Instruments

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WARNING
WARNING
FROM

TAG
Instruments

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Whether the need is for instrumentation to be "designed-in" at the planning stage, or improved instruments for present equipment or processes, the answer will be found in the complete Tag line listed above. Check this list against your instrument requirements, and write to us for complete descriptive literature and prices.

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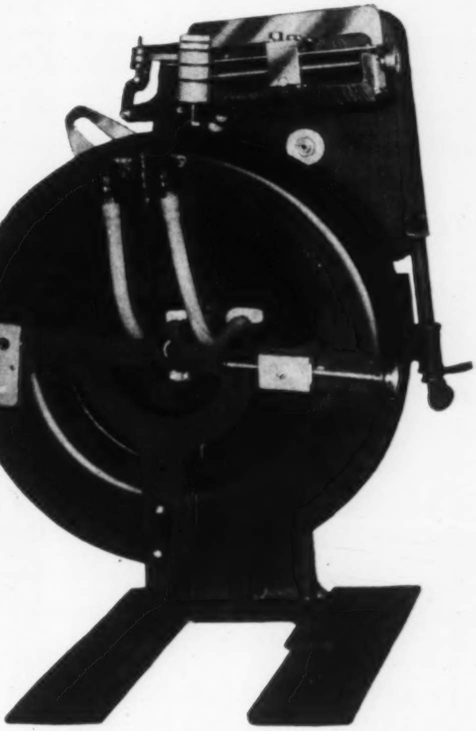

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R-S valvEvents

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Lots of Folks Can Make a Valve . . . .

Many machinists can make a valve. They don't even have to be very good machinists, nor have very good equipment because it probably won't be a very good valve anyway. In any event it will lack the engineering a valve requires if it is to stand up and deliver the service.

Big businesses with big shops often succeed in building a valve which will give service but they pay a fabulous price to do it, though the cost is often hidden in "shop overhead." Various people concerned believe they have saved money but accurate cost-accounting would prove this not to be the case.

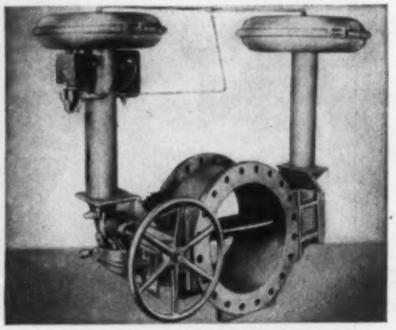
We recently saw a large valve built in the company shop by a manufacturer (not in the valve business) who boasted of a cost of only about $4,000. We couldn't have built the job in our own shop, specializing in valve construction, for less than $7,000, before figuring our modest profit. We know darned well no amateur valve-builder could build it for $4,000 either!

The days of the slap-happy stove-pipe damper masquerading as a valve are gone, and R-S Products with its rigid engineering standards has done much to banish them.

R-S Control and Shut-off Valves are as carefully engineered as a bridge or a building and there are just about as many stresses to figure to build a valve which will give full service with full safety factor, without waste of material or labor.

For Regulating Downstream Pressure

R-S Valve, Type No. 706, shown at top of next column, is a 24-inch 125-pound valve with two diaphragm motors, single valve-positioner and single pressure controller. Designed for regulation of downstream pressure. The vane opens with air failure. 80-pound pressure-drop across the valve demands the use of two diaphragm tops to get the needed power.



R-S Valve Type 706, 24 inch, 125 pound, with two diaphragm motors

Let's Get This Straight

Cast iron valves do not thrive in a temperature of 1400° F. Nevertheless, people ask for them occasionally. Russell Ayers, Sales Manager of R-S Valve Division, had another such inquiry recently, as reported to the Editor of ValvEvents.

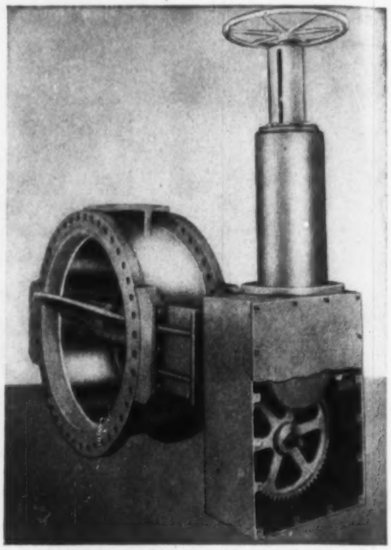
At 1400° F. a cast iron valve has long since lost all interest in flow control, not to mention shut-off.

Here's a brief rough guide on what various metals will take in the way of temperature:

Material	Elevated Temperature Limit
Cast Iron	450 deg. F.
R-S "H" Metal	1000 deg. F.
Carbon Steel	750 deg. F.
Carbon Moly Steel (½% Moly)	950 deg. F.
Chrome Moly Steel (4-6% Chrome ½% Moly)	1250 deg. F.
18-8 Stainless Steel	950 deg. F.
Chrome Nickel Alloy Steel (other than 18-8)	1250 deg. F. up to 2000 deg. F.

There are other factors just as important in the design of a valve as temperature. Therefore, we say the above is only a rough guide.

It is a good idea in addressing inquiries to us on valves to follow the list of working conditions on the inside back cover of R-S Catalog #17. If you haven't one, you'd better tell us and we'll send it.



R-S Valve Type 710, 48 inch, 125 pound, with renewable bronze liner

R-S Valve in High Head Water Service

Picture shows R-S Type No. 710. It is a 48-inch 125-pound cast iron valve with renewable bronze liner. This valve was built for water service and is now operating in a western dam under high pressure. The handwheel control has a gear reduction drive so that only 50 pounds of force is required of the operator to handle the valve even under highest pressure conditions.

The New R-S Valve Catalog #17

R-S Valve Catalog #17 is packed with information for engineers. There are over 70 halftone pictures of R-S Valves . . . working drawings of 21 types of R-S Valves with standard controls and fittings and complete dimensional data for all sizes . . . working drawings of 22 types of prime movers . . . numerous other diagrams, graphs and miscellaneous drawings. Address R-S Products Corporation, Valve Division, Philadelphia 44, Pa.

JMLco 41

Engineering Opportunities *in the* Field *of* Instrumentation*

A Guest Editorial

By E. G. BAILEY, 1948 President, American Society of Mechanical Engineers.

THE industries which depend most upon measuring instruments, meters, and automatic controllers are those of power generation, the chemical processes, and aviation.

The steam-generating plants have extended their requirements from a water column, a pressure gage, and a few thermometers to a complete complement of flow meters, gas analyzers, pH recorders, as well as a multitude of temperature, pressure, draft and level indicating and recording instruments. Complete electric generating units of 150,000 kw. are today under complete automatic control.

In the metallurgical industry, operation of blast furnaces, open hearths, smelters, heat-treating furnaces, and rolling mills are turning to measuring instruments and automatic controllers to increase production, decrease fuel consumption and improve the quality of the product.

The chemical processes involved in the production of synthetic rubber, rayon and nylon, alkalis, and other chemicals too numerous to mention depend upon instruments and automatic control for proper operation.

In the petroleum industry where heat-cracking and rectification are necessarily under accurate pressure and temperature control, instrumentation is considered a necessity.

At the beginning of this century the industrial instrument business was very meager, and even by 1920 it produced only about twenty million dollars' worth of equipment per year. Now it approximates an annual rate of two hundred forty million dollars.**

The cumulative value of this business, which falls largely in the capital goods class, is applied to the processing of many billions of dollars' worth of material in the chemical and allied industries. Measuring instruments and controllers have an appreciable effect upon improving the efficiency of combustion of several billion dollars' worth of fuel per year in the power and other industries. To the actual saving in fuel there should be added a great saving in labor due to the guidance of operators, enabling them to supervise very much greater outputs than could otherwise be handled per man.

There was a great impetus given to the Fluid Meter Branch of the Instrument Industry shortly after the turn of the century. This was brought about by a combination of needs growing out of the activities in other branches of engineering such as the development of the steam turbine and the rapid growth of the power industry. It was necessary to meter steam flow to determine the performance of both the turbine and the boiler. At the same time the chemical industry called for measurement of the flow of various fluids.

A group of users and manufacturers were instrumental in starting the Fluid Meter Research Committee of the ASME in 1916. The early committee members included:

R. J. S. Pigott, Chairman

H. Bacharach
E. G. Bailey
M. M. Borden
Edgar Buckingham
George S. Coffin
G. A. Dawley
A. R. Dodge
Lester M. Goldsmith
Sidney Fischer
F. G. Hechler
Horace Judd
Charles C. Lee
Leo Loeb
P. S. Lyon
H. N. Packard
W. Mapelsden
J. M. Spitzglass, Secy.
T. R. Weymouth

Mr. Pigott continued as chairman until 1947. The work done so far consists of background research, which helped the entire industry and all who have or ever will use fluid meters. The committee has collected and spent about $39,000. for determination of orifice coefficients and limitations in approach conditions, and the committee members have given freely of their time and talent to provide information for industry, the total value of which has been many times the cash expenditures. The ASME sold copies of these reports at a gross value of about $48,000. The work and activities are continuing in a healthy state.

The ASME has another field of activity which bears very closely on this industry, and that is the Power Test Code Sub-committee 19, which covers instruments and apparatus. This Sub-committee has already published thirty-five codes or chapters on twenty-one general headings. These collectively comprise over five hundred pages of literature on the general subject of measurements.

The importance of the instrument industry in times of war is discussed in a recent report, by a Committee of the Scientific Apparatus Makers of America, to the War Munitions Board. I quote at random from this report to emphasize the many phases of war preparation which require the help of the instrument industry in successfully carrying out their programs.

> "Synthetic rubber, high-octane gasoline, blood plasma, variable time fuses, radar and sonar, atomic bombs—these highly dramatic achievements have made us all aware that wars are won in the laboratories, on designing boards, and in industrial plants as well as on battle fields.
>
> "This statement is concerned with scientific and industrial instruments and equipment, with tools of modern scientists. First, instruments and apparatus he uses in laboratory, second, instruments which make it possible to adapt accurately controlled processes at the laboratory to requirements of quantity production, third, instruments used as components in munitions and fighting equipment.
>
> "Variety was endless . . . the market for instruments was so broad in both civilian and military fields that 20,000 or more different instruments could be sub-divided into major groups as follows:
>
> 1. Military, aircraft and nautical instruments.
> 2. Scientific instruments and apparatus designed primarily for laboratory.
> 3. Laboratory equipment.
> 4. Optical glass, lenses, and optical instruments.
> 5. Industrial process instruments including indicating, recording, and controlling instruments.
> 6. Electrical quantity measuring instruments.
> 7. Surveying and drafting instruments.
> 8. Instruments and equipment for testing physical properties and inspection of industrial production.
>
> "The conclusion to be drawn from the evidence submitted is that the Munitions Board should view the 'master key' scientific instrument and equipment industry as a vital war potential—a cohesive integrated industry with unique problems that must be solved in the interest of adequate defense."

To define broadly the so-called field of instrumentation: it is the art of automatic measurement, communication and regulation of factors and functions. Engineers in the future will utilize this branch of technology to an even greater degree.

Even though the needs of the various industries call for almost identically the same kind of pressure and temperature recorders, flow meters and the like, the instrument industry has learned that it is best for a given company to specialize in one or a few industries, instead of offering their equipment indiscriminately to all potential purchasers. This is because a given instrument-maker must do much more than make and sell instruments; he must sell intelligent service. He must have engineers trained and well versed in the many problems and operating details of the particular industry in which his equipment is to be applied. This is especially true when automatic control is added to the measuring instruments, and the purchaser wants a completely coordinated and engineered unit.

What are our opportunities? The answers are to be found in the fields where we now fall short of doing all that we are supposed to do. Today we should improve our equipment in several ways:

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*Luncheon talk, Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers, New York City, December 1, 1948.

**EDITOR'S NOTE.—By "the industrial instrument business," Mr. Bailey no doubt meant the segment thereof usually called "the recorder-controller group," which does not take in the manufacture of electrical instruments and meters, dimensional gaging and inspection instruments, positive-displacement meters, optical instruments, aviation instruments, etc. *The Wall Street Journal* recently gave an eight-times greater figure ($2,000,000,000) as the annual sales of instruments.—M. F. BEHAR.

1. Accuracy
2. Reliability
3. Responsiveness
4. Simplicity in function and construction
5. Usefulness to the operator or user
6. Application as insurance for safety and protection, including indirect detective use
7. Intelligent application to industry.

To comment on the improvement of the types of equipment now being made as enumerated above:

1. Accuracy is the important goal of all instrument manufacturers. The degree of accuracy should, however, not be carried to extremes beyond that really needed. The cost of high accuracy is not always justified. Maintained accuracy to an economic degree is equally desirable. There is need to check and adjust the accuracy by the user and suitable instructions and provisions are essential.

2. Reliability as to ruggedness or dependability may seem to be synonymous with accuracy, but it is used here as a measure of the suitability of the construction of the equipment to the conditions under which it is used. An instrument of satisfactory accuracy on a permanent base may be useless on a locomotive or an airplane. The crash of United Air Lines Flight 624, a Douglas, aircraft NC-37506, near Mount Carmel, Pennsylvania, on June 17, is now reported by Civil Aeronautics Board as of unknown origin. There is a possibility that the pilot was incapacitated through presence of CO_2 in an effort to extenguish a fire, which may have been imaginary owing to the stated unreliability of the fire-indicating system. The results of hearings are not yet published.

Why is it that on the dashboard of all automobiles most speedometers give satisfactory service throughout the life of the car while the clock often fails after a relatively short time?

3. Responsiveness or little time lag is important in many cases while in others reasonable time lag is permissible. As the output or throughput of heat exchangers, fractionating towers, furnaces and other apparatus in the power and process field is increased and the ratio of size to output reduced, the heat capacity storage is minimized and the need for more responsive measuring instruments and automatic controllers is increased.

Measuring devices and automatic controllers having full-scale response in seconds or fractions of seconds are now required in many applications in the process industry.

Among E. G. BAILEY's inventions are fluid meters, boiler meters and automatic combustion controllers as well as furnaces. In 1916 he founded the Bailey Meter Co. and was its president until 1944 when he became Board Chairman. He is vice-president of The Babcock & Wilcox Co.

INSTRUMENTS ON THE MARCH
Front-cover photo
METERING OPEN-HEARTH OXYGEN

Accurate metering of oxygen employed in steel mills—for carbon reduction in the open-hearth melt, for direct scrap meltdown, scarfing, and other operations, is essential to cost control, and for sound evaluation of this relatively new development in steel technology. Oxygen flow and pressure are likely to fluctuare sharply, over a wide range, so that meter requirements are unusually severe. The instruments must be extremely sensitive, accurate at either high or low flows, easily adjustable and generally require automatic pressure compensation. Perhaps most important, operation-wise, the oxidation of mercury in the meter must not affect its calibration. The above view of carbon reduction by use of an oxygen "lance" was made at Jones & Laughlin Steel Corporation's South Side Works, Pittsburgh. *(Both photos courtesy Hagan Corporation)*

4. Simplicity in function and construction. This point more than any other shows the significance of the maker. In the early designs this was more noticeable than now as we have all learned from, and emulated better designs of others. Some designers are prone to approach a problem in a complicated and profuse method. It is always best to strive for every part to serve two purposes, but some still use two parts where one would do.

5. Usefulness to the operator or user. In view of the basic purpose of an instrument to measure a condition and transmit that information to the operator, it is important that the information should be quickly and accurately imprinted on the minds of the operator, both as an instantaneous reading and as a chart record.

There has been an unfortunate inconsistency and diversity incorporated in the design of many instruments. For increasing values some instrument indicators move upward, some downward, some to the right, some to the left, and others at different angles.

To follow records with respect to elapsed time, some charts must be read from left to right, and others from right to left. Some circular charts must be read counterclockwise while others rightly read clockwise. It would be desirable if all charts could be strip or circular, but there is and probably will remain ample need to use one type for some purposes and the other for certain other uses.

Two years ago at the Pittsburgh meeting of the ISA, in which this ASME Division participated, Admiral Luis de Florez gave a very interesting talk on the need to have all instruments designed for easy reading and accurate understanding by the operator. The following is quoted with permission.

> "In aviation it is recognized that instrumentation has become so complex that we have reached the limit of the man of average ability to utilize the information that is poured into the cockpit. We have at least begun to think of the presentation of readings of instruments in such form that our mental processes can readily assimilate the knowledge conveyed, and thus reduce the hazard and fatigue and the effort necessary to form a picture of flight attitude and engine operation. This trend represents a new philosophy of instrumentation, which is to present instrument readings in such manner that the pilot can react instinctively to them."
>
> "Future instrumentation must take into account the psychological and physical characteristics of the operator to be successful, which inevitably leads us to physiological and psychological research as part of the work to be done in the field of instrumentation. Readings, lighting arrangements, air conditioning, methods of presentation, and other factors that will make understanding easier to the man of normal acuity must be studied and explored singly and together. We must consider the whole control panel as one instrument and endeavor to utilize the instinctive human relations to portray the operating conditions. If we glance about us with this thought in mind, we can readily appreciate the tremendous amount of work that has to be done and, by the same token, the great opportunity that lies before us. Man's intellect does not change, but our machines are progressing by leaps and bounds. The average mentality has become a major design factor, and we must heed it from now on."

In a paper read by Dr. Walter F. Grether before the American Psychological Association, evidence was presented of the difficulty in reading some aircraft instruments. Part of the blame for this was put on the designers of these instruments.

> "There is probably no other field of activity in which human errors are so costly as in aviation. Statistics for military aviation normally show approximately 70 per cent of aircraft accidents to have resulted from 'pilot errors' in one form or another. Although this figure is probably somewhat higher than it would

Concluded on page 70

The Physical Principles *of* VACUUM MEASUREMENT *and* PRODUCTION*

By C. H. BACHMAN, Physics Department, Syracuse University.

IN this field the physical principles are quite well established and for many workers the interesting phases are in the fields of associated gadgetry. However, this article is held to a discussion of the basic principles and the gadgets must be put to one side.

First, what is a vacuum? A perfect vacuum is easy to define although it seems impossible of achievement. We have a perfect vacuum in a space only when we have removed the last particle of gas. Since this can never be realized we must deal always with partial vacua. Now, a definition of partial vacua is somewhat easier. A region under partial vacuum has had *some* of its gas molecules removed.

Such a definition can lead to interesting results. For instance, if you were in a high-pressure room at, say, ten atmospheres pressure, and you removed one-tenth of the gas from a container you might have with you, that container could be considered to be under partial vacuum, whereas if you brought it out of the high-pressure room it would be under nine atmospheres of pressure. This comes about because we usually work under conditions of one atmosphere pressure which is the pressure of the air above us. To a first approximation this is stable, varying only a few percent at a given elevation. We usually consider a region to have a partial vacuum if gas surrounding that region tends to diffuse into the region.

We can divide partial vacua into three broad classes. The first includes those applications where the pressure is reduced only slightly below atmospheric—possibly just enough to establish a directional flow. We will not be interested in this class. Phenomena associated with these vacua are nearly like those at atmospheric pressure. We will not concede even that it is a vacuum, but consider it as "reduced pressure."

If we lower the pressure so that possibly only 1 percent of the gas remains, we then can say that we have a rough vacuum. New and characteristic phenomena become evident. For instance, we can set up gas discharges such as are found in neon lamps. The relatively few molecules remaining in the space find they can move around through greater distances without colliding with one another. We say that they have a greater mean free path.

Now, if we lower the pressure still farther, removing more and more of the molecules, their mean free path becomes longer and longer and their chances increase of reaching the container walls instead of colliding with one another. As this condition is reached a new set of characteristic phenomena appear and we have reached the region of *high* vacuum or *fine* vacuum. Although there is no sharp dividing line, a definite natural boundary exists which becomes evident in pumps, gages, and many vacuum applications—both chemical and physical.

TABLE I -- CONVERSION OF PRESSURE UNITS

	Dynes/sq. cm. (Barye, Microbar)	Grams/sq. cm.	Pounds/sq. in.	Atmospheres	Mm.Hg (Tors)	Microns	Bars
Dyne/sq. cm. (Barye, Microbar)	1	1.0197×10^{-3}	1.4504×10^{-5}	9.8692×10^{-7}	7.5006×10^{-4}	7.5006×10^{-1}	1×10^{-6}
Gram/ sq. cm.	980.66	1	1.4223×10^{-2}	9.6784×10^{-4}	7.3556×10^{-1}	7.3556×10^{2}	9.8066×10^{-4}
Pound/sq. in.	6.8947×10^{4}	70.307	1	6.8046×10^{-2}	51.715	51.715×10^{3}	6.8947×10^{-2}
Atmosphere	1.0133×10^{6}	1.0332×10^{3}	14.696	1	760	7.6×10^{5}	1.0133
Mm.Hg (Tor)	1.3332×10^{3}	1.3595	1.9337×10^{-2}	1.3158×10^{-3}	1	1×10^{3}	1.3332×10^{-3}
Micron	1.3332	1.3595×10^{-3}	1.9337×10^{-5}	1.3158×10^{-6}	1×10^{-3}	1	1.3332×10^{-6}
Bar	1×10^{6}	1.0197×10^{3}	14.504	9.8692×10^{-1}	7.5006×10^{2}	7.5006×10^{5}	1

This table gives the value of the pressure unit named at the left in the units named at the top. For example, 1 atmosphere is 760 mm.Hg.

It always is desirable to have convenient units for purposes of reference and discussion; and the field of vacuum practice has its share as is shown in Table I. Some of these are of historic interest only. For our purpose we will use the units mm. Hg (one atmosphere is 760 mm. Hg) and microns (one thousandth of a mm. of Hg). Then our rough vacuum might correspond to pressures from a few mm. Hg down to about a micron. Below that, from one micron (10^{-3} mm. Hg) down to the fairly commonly attained 10^{-7} mm. Hg and the more difficult 10^{-9} or 10^{-10} mm. Hg, we will say that we have a fine vacuum or high vacuum.

At about one micron, the region where fine vacuum phenomena appear, the mean free path lengthens to the order of centimeters for most common gases and this also begins to approximate the dimensions of the apparatus. Thus the gas particles can be treated as individuals. They have a chance in their lifetime of doing something besides colliding with one another. As stated, the

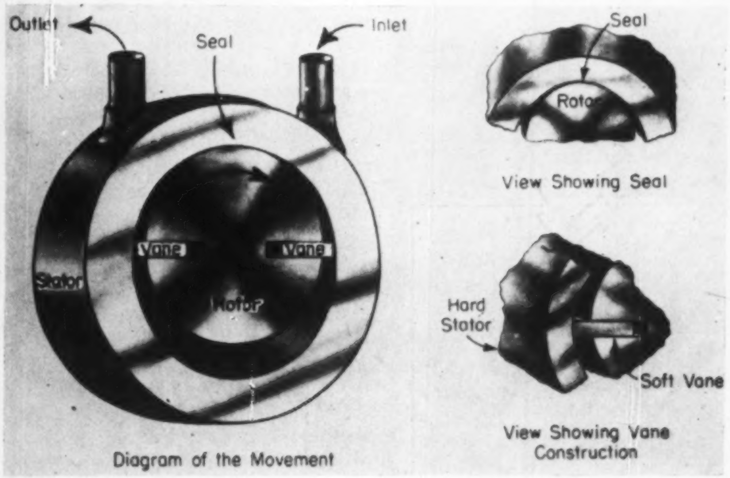

Fig. 1. Pumping Mechanism of the Welch Duo-Seal Pump. (Courtesy Welch Scientific Co. Chicago)

dividing line is not sharp. It depends upon the gas, the geometry of the apparatus, and the phenomena under observation. The region is usually between one-tenth of a micron and ten microns.

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*Presented at the American Institute of Physics Session on Scientific Instruments of the Third Annual Conference of the Instrument Society of America, Sept. 15, 1948, Philadelphia, Penna.

Next let us consider the means of obtaining vacua. It is impossible, of course, to get into a vacuum chamber and remove each gas molecule personally. We revert, therefore, to a strategem and make use of a weakness shared by gas molecules. In their random motions they are always looking for *lebensraum*: if they see a vacant space they immediately move in and take over. Technically speaking, they diffuse into regions of lower pressure. Therefore, if we can keep removing gas from a part of the vacuum system, we will eventually reduce the pressure of the whole system.

Two general types of pumps are commonly used in vacuum practice — mechanical positive-displacement pumps, usually rotary; and vapor diffusion pumps. Many commercial variations are available using the same basic idea for the mechanical pump. A housing (see Fig. 1 for one type) contains a rotating member and sliding vanes sealed in oil. Gas admitted to the pump is compressed and allowed to escape to atmosphere. The pumping speed of such a device depends upon its size and speed of rotation. Pumping speeds from a few liters a minute to many hundreds of liters a minute are commercially available. The degree of vacuum obtainable is well below a micron. In actual practice, however, one is fortunate to obtain vacua under 10 microns consistently. This is not necessarily due to a shortcoming of the pump, of course, as the condition of the vacuum system may be the controlling factor. Pump speeds drop off rapidly below a micron.

When a better vacuum is required than that obtainble with the mechanical pumps, it is customary to place a vapor diffusion pump in series between the mechanical pump and the vacuum system as shown in the block diagram of Fig. 2.* The operation of this type of pump can be explained by the simple one-jet device shown in Fig. 3. Vapor—usually either mercury or a specially-prepared oil—leaves the heated boiler and emerges from the nozzle in a unidirectional jet. Gas molecules from the vacuum system diffuse into this region where they mingle with the pump vapors and are given a boost along toward the exhaust port which is in reality the inlet to the mechanical pump.

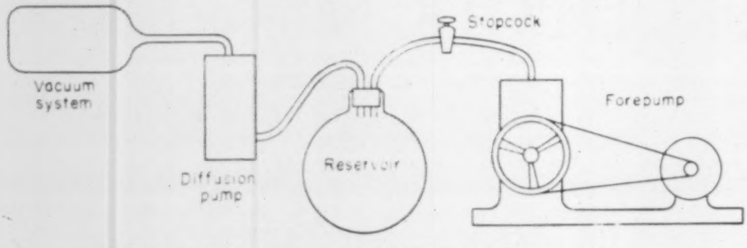

Fig. 2. Series Arrangement of Pumps in a High-vacuum System.

The pump vapors having performed their duty condense out on the pump walls and the liquid returns to the boiler where it can again start its working cycle. The evacuated gas enters the mechanical pump which exhausts it to atmospheric pressure.

Vapor pumps cannot exhaust into atmospheric pressure. They require a "fore pressure" or "forevacuum" of 20 microns to a mm. Hg depending upon the pump design. Mechanical pumps when used in this capacity are called "fore pumps" or "backing pumps." The speeds of vapor pumps are generally higher than those of mechanical pumps, usually being rated in terms of liters per second rather than the liters per minute of mechanical pumps. Pumps having speeds of one or two liters per second up to thousands of liters per second are available.

The performance of a vapor pump is determined by the efficiency of nozzle design, the type of pump fluid used, the number and size of stages and the fore-pressure. Under the best conditions, with good pumps, all-glass baked out systems, etc., vacua of 10^{-7} mm. Hg are not too difficult to obtain. In the so-called dynamic or demountable systems where metal and rubber parts are present, 10^{-4} or 10^{-5} represent good values. In either case the mean free path is such that high vacuum conditions prevail.

Various phenomena are available for measuring the degree of vacuum. Again we will neglect the region above about 1 mm. Hg where Bourdon gages and simple U-tube manometers are used.

One of the oldest and most useful of vacuum gases is the McLeod. In this gage (Fig. 4), a known volume of gas at the pressure of the vacuum chamber is tapped off and compressed into a capillary. This compressed gas is then balanced against a column of mercury and, from gas laws, the original pressure can be determined. The gage can be made sensitive from about 1 mm. Hg down to approximately 10^{-5} mm. Hg. It has the advantage that its readings depend upon its geometry. In other words the gage can be calibrated quite accurately from a knowledge of its dimensions. For this reason, it is commonly used as a standard for calibrating other gages. It has the disadvantage of using mercury which has a relatively high vapor pressure at room temperature and so must be "trapped" with a refrigerant. Also, the gage does not indicate condensable gases.

Next, there are several gages sensitive in the vacuum range of 1 mm. Hg down to 1 micron which depend upon the removal by gas molecules of heat from a sensitive element. The better the vacuum, the less heat will be removed. This phenomenon can be used in a number of ways.

In the Pirani gage, a balanced bridge circuit is arranged with a fine wire filament in the gage as one arm of the bridge. (See Fig. 5.) Current is passed through the circuit, tending to heat the filament. Different temperatures will be reached by the wire, depending upon the gas pressure. These variations in temperature result in resistance varia-

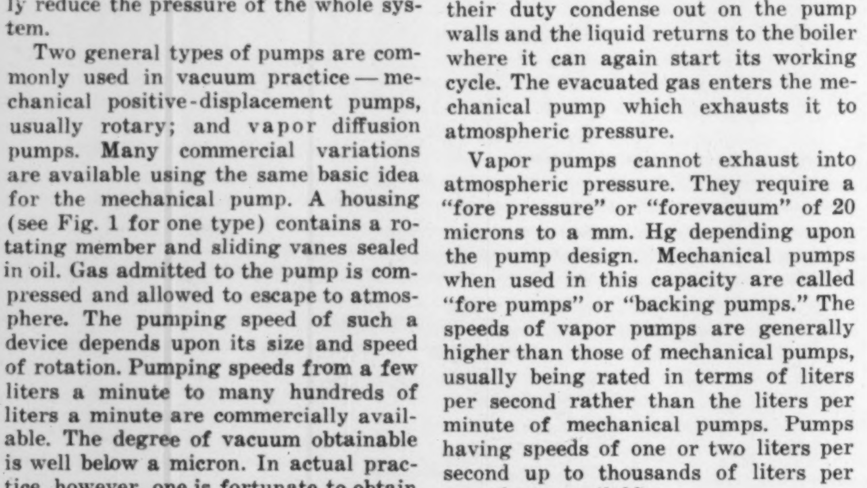

Fig. 3. Molecular Vapor Diffusion Pump Types.

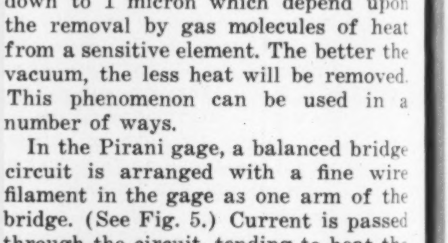

Fig. 4. Operating Principle of McLeod Gage.

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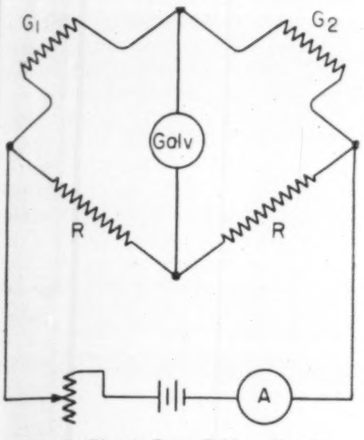


Fig. 5. Pirani Gage Bridge Circuit.

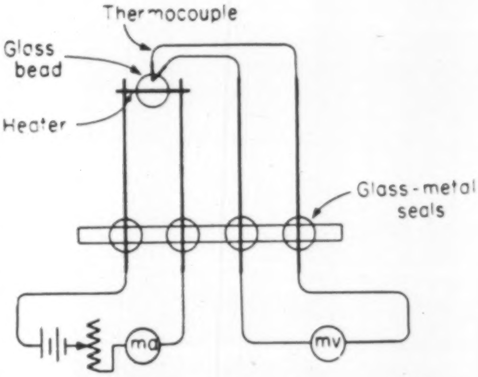


Fig. 6. Simple Circuit for Thermocouple Gage

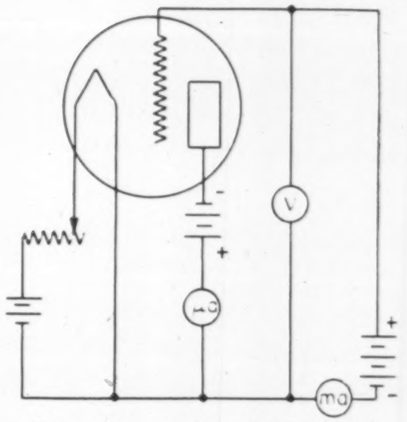


Fig. 7. Simple Circuit for Ionization Gage.

tions which throw the bridge circuit out of balance. The amount of this effect can be calibrated against the pressure.

In the thermocouple gage the fine filament, heated by the passage of current, is arranged to heat a small thermocouple (see Fig. 6). In this case the thermocouple output is a measure of gas pressure and can be calibrated.

The thermistor, whose resistance is very sensitive to temperatures, has been used for vacuum indicating purposes, suitable resistance-measuring equipment being necessary.

These gages all depend upon phenomena exhibited by a fine wire or ribbon which is subjected to temperature changes as a result of the cooling effect of the surrounding gas. In such gages the kind of gas is one of the variables—different gases having different cooling effects.

In the region below a micron the phenomenon found most useful is that of ionization. In the ionization gage a predetermined supply of ionizing particles is fed into the ionizing region. The positive ions formed are collected by a negatively charged plate (see Fig. 7). The number of positive ions collected is an indication of the gas pressure. A version of this gage, commonly called the Philips gage, imposes a magnetic field to give the ionizing particles a helical path. This longer path insures greater ionizing efficiency and therefore greater sensitivity. Although most ionization gages use electrons as the ionizing particles, the National Research Corporation's "Alphatron" makes use of particles from a radioactive source. Ionization gages have different constants or calibration curves for different gases.

I have discussed so far only the most commonly-used vacuum gages. There are many others based on other principles. Among these are the Knudsen gage, the vibrating quartz fiber, the gas discharge "Skanscope" and, although not a gage but a useful indicator, the spark-coil-generated glow discharge.

Now, in discussing pumps it was mentioned that one arrangement might pump down to one value, some other arrangement to some other value, etc. The accent was placed upon ultimate vacuum achievable. A field which I should like to discuss is that of holding a vacuum accurately to a predetermined value. This is essential in some operations and desirable in many others. Those who have done it know that it is not always easy. Two methods are available. In one, the pumps are allowed to run continuously and balance is obtained at the desired vacuum by the introduction of gas, either by generation within the system or (more commonly) by controlled leakage from without. The rate of leakage required is usually quite low; and means for controlling the leakage rate may make use of very finely drawn capillaries, the porosity of materials such as unglazed porcelain, and constrictions such as are obtained with flattened copper tubing. Such control means are not too reliable. Small dust particles play havoc with capillaries. The range of control possible with a given controlled leak is neither predictable nor large.

In spite of these drawbacks, this method is used more frequently than the alternative. In this other method the system is made as tight and clean as possible and the pumps applied. When the desired vacuum is reached, the system is closed off from the pumps and it is hoped that the gas pressure will not rise too rapidly. When it does, the system is again pumped down.

Both methods leave much to be desired. Most attention has been given to the system where a controlled leak is balanced against a fixed pumping rate.

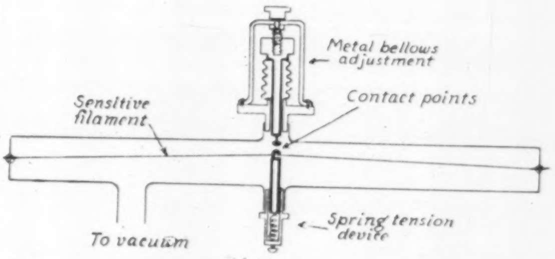


Fig. 8. Thermal Expansion Type Vacuum Switch and Indicator.

Little if any attention has been given to the control of the pumping rate. This is understandable in the case of high vacua where vapor pumps are used, since they are not amenable to speed control. Either the pump is working or it is not. In the region handled by mechanical pumps, however, there is a good possibility of control either continuously through speed of drive or by closely controlled intermittent pumping action. Continuous speed control as dictated by a gage is quite possible. However, with standard pumps and motors, this method would be rather expensive and complicated. The intermittent control, either of the pump or a solenoid valve, would seem to offer better possibilities. An experimental model of a control gage based on the thermal expansion of a heated filament is shown in Fig. 8. This device carries a pair of contact points which can control signal means, or, as we will discuss, a relay in the pump motor line. There are two methods of obtaining a setting for a desired vacuum. The metal bellows method is shown. This device adjusts the gap between contacts so that closure occurs at a desired expansion (pressure). In the second method, the bellows mechanism can be eliminated and a fixed contact spacing retained in which the heating current through the filament is controlled to give closure as desired. This device will stop and start the pump automatically and I have held pressures constant to better than 10% with it from a few microns up to several hundred. I believe that the sensitivity can be substantially increased and I am continuing to work in this direction.

While I was working with this control, the Skaneateles Manufacturing Company made available to me an experimental model of a control device which is now commercially available and which appears to have a remarkable sensitivity. Fig. 9 shows the instrument case containing the control equipment. The gage tube proper consists essentially of a pair of ring electrodes supplied with about 3800 volts. Conditions are such that the resulting gas discharge is of the abnormal type. The current flow in such a discharge is quite sensitive to pressure and, in this case, the current is fed into a simple control circuit which may be used to actuate signalling or controlling devices. When used in the pump motor line it is possible to start and stop the pump very closely around the pressure for which the control is adjusted.

The device is extremely sensitive. In operation, the pump at times will turn through only part of a revolution before it is again shut off. Measuring the vacuum with a continuously-indicating thermocouple gage, I have used these monitors or vacuum switches to hold the pressure in a system to variations of less than 1%. This control gage is now available for the range of a few microns up to a mm. Hg. Since it appears to have extremely stable characteristics, and there is nothing to burn out, the device would seem to be well adapted to industrial as well as to laboratory use.

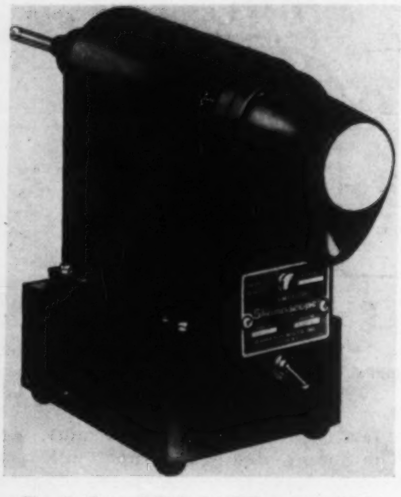


Fig. 9. Control Unit for "Skanascope" Vacuum Monitor. (Courtesy Skaneateles Mfg. Co., Syracuse, N. Y.)

Both the commercial instrument and my thermal expansion device could be adapted to be used for ordinary indicating purposes. I believe, however, that their greatest value lies in the field of accurately controlled vacua. This field is quite broad and includes both industrial and laboratory applications.

For instance, in my experimental work in connection with gage sensitivity, it has been a great relief to be able to hold the entire vacuum system to one vacuum value, study all the desired parameters, and then set for another value. Heretofore, it has been necessary to try to get the information "on the fly" as the indicated pressure passed through a point or else do the balancing technique with the pumps and a controlled leak.

In many applications a specific gas atmosphere is required at some desired pressure. With this new control technique, the gas can be admitted continuously and slowly at a fixed rate and the pressure adjusted by controlled pumping. Variations in leak rate for any reason are automatically cared for. I have not yet had opportunity to control the pumping rate by an intermittently-operated solenoid valve, but it should prove just as sensitive.

It should be pointed out that controls actuated through pressure-sensitive devices are not new. The literature has many papers describing means of turning off hot filaments or associated equipment when the pressure rises excessively. However, I know of no applications such as I have described here for holding the system at a desired vacuum. I hope that my discussion here may stimulate interest in this field which has been so peculiarly neglected and which potentially is so useful.

I wish to thank the Skaneateles Manufacturing Company for their coöperation in making equipment available.

The INSTRUMENT TROUBLE-SHOOTER

By H. K. MONK, E. I. duPont de Nemours Co., Belle, W. Va.

UNTOLD amounts of brain power and of scientific knowledge have been expended in the development of newer and more complicated instruments, which will undoubtedly do even better jobs of measurement and of automatic control.

But what about those of us—you and me, the Instrument Men—who must service and maintain these "Rube Goldberg" contraptions? Is anything being done to help us do an increasingly more complicated job of keeping in proper operating condition these Instruments of higher production, lower costs, and higher-quality product?

Classes are held annually during ISA conferences. In some industrial centers there are trade schools to attend; and wherever you live there are correspondence courses to take and books to study. More manufacturers' instructions roll off the printing presses and mimeographs than a man could read in a year—let alone study. There is "on-the-job" training and even the war-born "thirty-day wonder" training. All these to help us know How and Why an Instrument does as it does. In some of the instruction manuals there is even a Table or an Index, in cause-and-effect style, of a lot of Instrument failures.

But most of our failings are due to our own "knot-headedness," not our lack of intelligence, but our inability to think straight.

It is the purpose of this discussion to point out how and where we can all improve our ability to think straight, to add that extra punch—to solve problems.

You Instrument Men have proved your ability to solve problems in a wide variety of circumstances—anything from a simple pressure gage to electronic calculators and cascade control systems. You Instrument Men are called on to find out what's wrong with very nearly anything that isn't working.

Just the other day a man from the laboratory called and said he had some kind of dish-washer which would not work and the electrician had put in six (6) fuses in the last six (6) minutes and the fool thing had only rotated six (6) times.

After the Instrument Man turned over one of the trays—which had been installed wrong—the machine started off merrily and we haven't heard from it since.

That's not unusual! Instrument Men make good trouble-shooters on all kinds of gadgets. Why can't we be good trouble-shooters on Instruments?

I dare say none of us knew in advance what we were going to be called upon to know when we got into the Instrument field.

We more-or-less drifted into it.

There was no formal schooling, no formal apprenticeship courses to take, and very little written about Instruments, which would prepare us for the job ahead.

With Instruments being used the way they are today, an Instrument Man is called in almost every time there comes up a case of operating difficulty.

Not long ago an operator was pumping material from a tank, and it was important that he pump out just the right amount for this batch type process.

He had everyone all excited because he was getting false readings on the tank gage manometer. Also, the material wasn't flowing out of the tank fast enough to suit him.

After checking the installation briefly, the Instrument Man asked if the tank vent was open.

The operator and everyone assured him that everything was all right. Why, the electricians had checked the motor; and the millwrights had just overhauled the pump; and the pipe lines had all been taken out and cleaned just a few days before—it must be that darned Instrument!

After more questioning, the Instrument Man found that a pressure seal had been installed on the vent line. It's a wonder the tank hadn't collapsed.

In order to solve our day-to-day problems, we must constantly add to our store of knowledge, which may include anything from simple arithmetic to the theories of nuclear physics.

The man who consistently solves his problems is not just plain lucky, nor has he faced this particular problem before: He has trained himself to be a logical thinker.

This logical thinker is known as a good trouble-shooter.

His reputation is a goal toward which we should all strive.

Let us look at this man and see why he solves the problems when so many of us fail.

His formal education was probably no better than ours; but he has retained his knowledge of mathematics, chemistry and physics, which he uses to advantage.

His experience is probably no broader than ours; still, he has paid attention to details to such an extent that he can look at an instrument part and tell you where it goes and what it is for, even though he may not have seen the instrument for a long time.

Is his workmanship any better than ours? Not necessarily. There are other good mechanics—some, maybe even better. But he always uses the correct tools for each job.

He always leaves the job clean and orderly. No unfinished details for him: his job is always complete.

Yet, all of these are only minor differences, which still don't explain why he can get things working so quickly.

Just the other day a man was called to service a controller which had been hunting for several days.

Several good mechanics had checked every part and made every adjustment, but no one had found the trouble.

He looked at the chart for a while and, while talking to the operator, he gently moved the pen up the chart, then down.

Turning to the operator he said, "I believe that it will control O.K. when I correct the lost motion in the pen mechanism."

And so—another problem solved!

This good trouble-shooter never takes anything for granted, yet he doesn't have to check everything when looking for trouble.

He usually checks only two or three things and finds the difficulty.

He must do a lot of fast thinking.

But the rest of us can think fast, too. Maybe it's the way he thinks that counts.

He never guesses about a thing. When he doesn't know all the facts, he stops to think it through. He has reason for everything he does.

Not long ago a new temperature recorder was put in service and, soon after, an operator called to say that one of the couples seemed to be reading about 20 degrees low.

The good trouble-shooter told the operator that this didn't sound right for a six-point Instrument but that he would look at it.

When he arrived, he checked only one thing, the selector switch, to see if it was open on that point.

When it wasn't, he reversed the leads in the Instrument, then went outside and reversed them again at the couple. Everything was O.K. Another problem solved!

He later explained that the Instrument must have been all right otherwise the rest of the couples would have been low.

But—how did he discover what was wrong so soon after getting there?

He noticed that the chart indicated a gradual rise in this couple, and by the same amount as the outside temperature.

He also noticed that the difference now was about the same as that between room temperature and outside temperature.

In other words, he used his reasoning power to solve a problem.

This is the basic difference between a good trouble-shooter and a good instrument mechanic. His reasoning was a deliberate and critical use of his knowledge to solve a problem.

Some of us may wonder if we can learn to reason.

Undoubtedly we are born with different degrees of reasoning power, but we can all improve by conscientious effort.

Let us take in proper order the steps of reasoning:

The first step is recognition that a problem exists.

This depends mainly upon our knowledge of the correct performance of the Instrument. We can gain this knowledge only by taking enough interest in our work to study, and learn as much as possible, before we are called to do a job.

Never pass up an opportunity to learn anything new!

The second step is careful examination of all the facts—both observed and retained from previous experience.

The most important part of this second step is to notice the little details. These little details often limit the number of possible answers to the problem.

In the third step, we must imagine all possible answers and eliminate them one by one until we have chosen the most likely to be correct.

In the fourth step, we are ready to prove or disprove our most likely choice. We must be adventurous enough to try out this solution; otherwise our solving the problem is a waste of time.

The fifth step is realization that the problem no longer exists: We must know enough about the Instrument to know when it is operating properly.

In running through these steps of reasoning, it can be seen that we can all improve our ability to solve problems.

There are, however, three main sources of error in our reasoning.

We must constantly guard against them.

In the order of their importance, they are:

First. Delusions.—This means that we believe what we want to believe. In other words, we are not indifferent to the outcome of our decisions.

Second. Rationalization.—This happens when we spend time justifying ourselves for the action taken. A pure waste of time!

Third. Indecision.—This is a result of trying to reason about every action. After once reaching the solution to a problem, we should automatically reach the same solution again, when faced with the same problem. Thus it becomes a habit.

When we are guilty of any one of these three errors in our reasoning, or when we do not constantly strive to add to our store of knowledge, we are unmistakably limiting our ability to solve problems.

With such fast development in our field of work, we must all develop our trouble-shooting ability.

There are many times, however, when it should not be necessary to stop and analyze all the possibilities of error. Some jobs which are of a repetitive nature we should form the ability to do by habit, leaving ourselves free for greater activity and more productive thinking.

To meet the needs of our fast-growing field of work we will need more and more people capable of solving complicated problems.

From past experience, technical men are included as well as the service mechanics.

The future of a good trouble-shooter looks more promising every day.

Industry is constantly looking for good trouble-shooters.

Let's not wait for necessity to drag us out of our mental laziness.

Let's meet the future half-way by improving our ability to solve problems.

Remember: you can improve your reasoning. The first step is to recognize that a problem exists.

Are YOU the Problem?

Radio-frequency Mass Spectrometry—A Promising New Analytical Method

By WILLARD H. BENNETT, Chief, Physical Electronics Section, Atomic and Molecular Physics Division, National Bureau of Standards, Washington, D. C.

INVESTIGATION of the conditions for the formation of negative atomic ions of the heavier metallic elements has led to the development of an extremely valuable method for detecting, separating, identifying, and measuring such ions.

Since negative atomic ions, consisting of atoms with extra electrons, have very low energies of formation, their study has been difficult because of the rapid dissociation of the ions in very short distances of travel; that is, before they can reach a measuring electrode. The exacting requirements have now been met by means of a specially-designed vacuum tube which provides a greatly simplified and flexible radio-frequency mass spectrometer.

This spectrometer not only opens up a new means of exploring the little-known fundamentals of negative atomic ions but its characteristics make it widely applicable for other uses, including the mass spectrometry of positive ions.

Negative atomic ions have been detected for only a few elements since they were first discovered about forty years ago, although accepted theory has indicated the possibility of producing such ions from many of the elements. Experiments begun at the NBS in 1946 indicated that negative atomic ions might well exist in the many familiar forms of electrical discharge in vacuum tubes, but that they would not be detected if the distance through the tube between the discharge and the electrode was large. It was necessary, therefore, to devise an experimental method for separating and identifying such ions within distances of a few centimeters. This was accomplished through the new mass spectrometer tube.

In its more advanced form, the three-stage spectrometer may be used for positive ions as well as negative ions. The equipment consists essentially of a multigrid tube in which an adjustable radio frequency is applied to three grids while all other electrodes are held at the proper d-c. potentials, and the ion current is measured at the plate. The more exacting requirements of negative-ion separation require the use of a small magnetic field produced with coils, but, if positive ions are being separated, no magnetic field is needed. Because large electromagnets or tubes containing electrodes with elaborate slit systems are not required in this method, the radio-frequency mass spectrometer should find wide application where its resolution is sufficient and where the expense of the more elaborate, conventional beam-deflection equipment is not justified.

One of the principal limitations upon the resolution possible with the ordinary mass spectrometers using magnetic deflection of beams has been the spread in energies of the ions at the ion source. The percentage spread occasioned by this factor can be reduced by increasing the voltage applied to the ions before they are magnetically resolved. The extent to which this can be done is limited, however, by the magnetic field that can be obtained in a space sufficient to contain the tube.

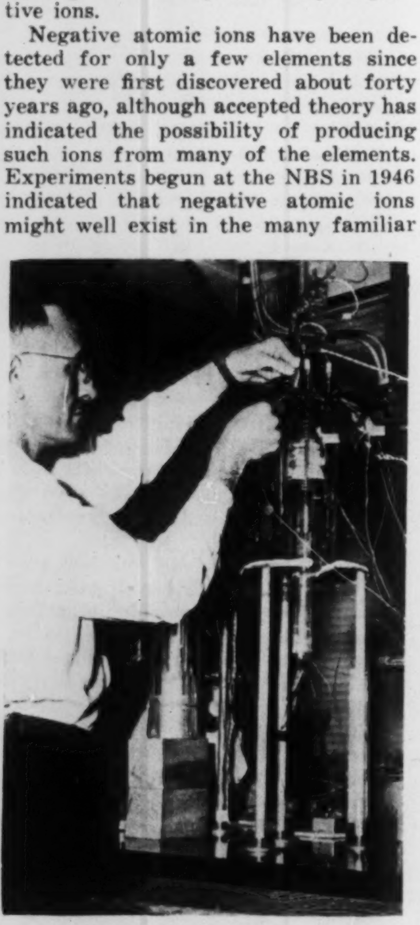
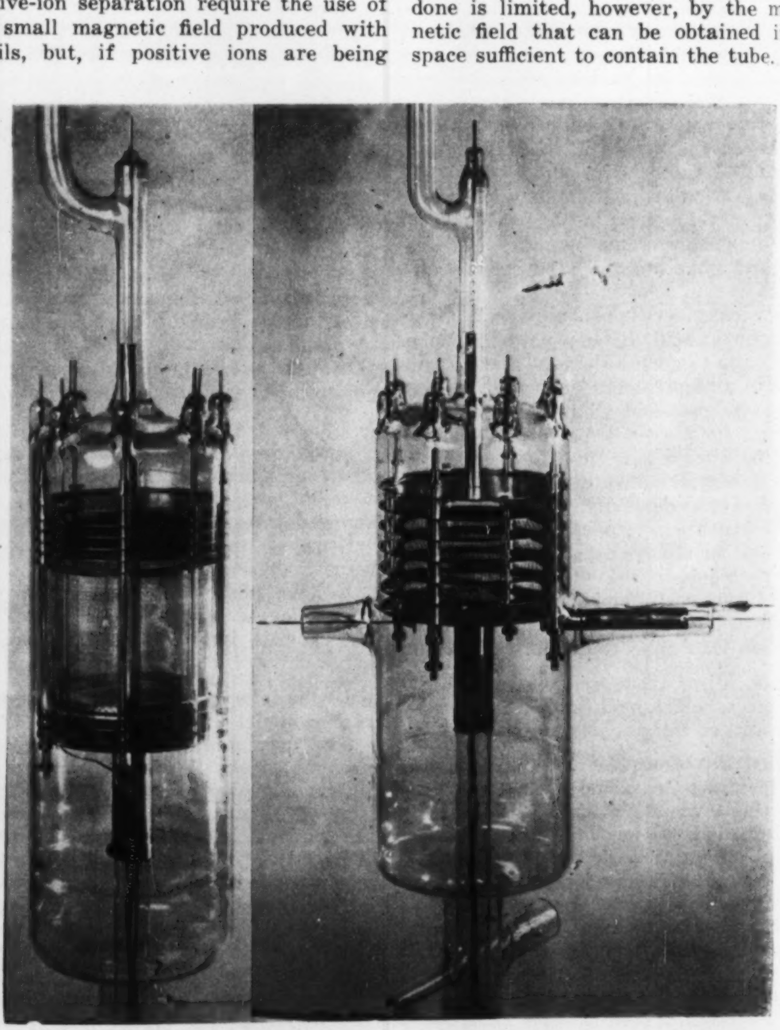


Fig. 1. Adjusting the new simplified and flexible radio-frequency mass spectrometer at the NBS.



(Left) Fig. 2. Close-up of the new two-stage nine-electrode radio-frequency mass spectrometer. *(Right)* Fig. 3. Special negative-ion research tube developed at the NBS to meet the exacting requirements of negative-ion investigation.

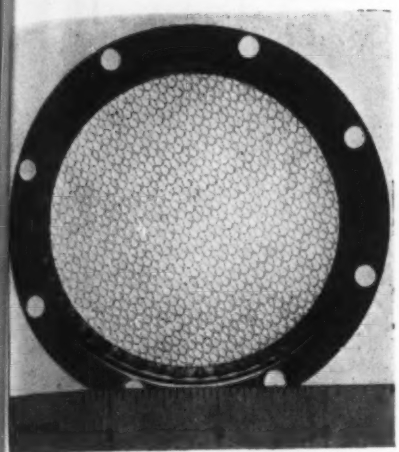


Fig. 4. Close-up of the type of grid utilized in the new r-f. mass spectrometer. The 95% open area makes the large number of grids (electrodes) practical and is one of the essential new factors in the NBS tube.

In the radio-frequency mass spectrometer, this difficulty is eliminated, and the voltage of the ions can easily be pushed up at least an additional order of magnitude to any value for which insulation can be provided. The frequencies required are then increased by an amount equal to the square root of the factor by which the voltage is increased. Raising the voltage from 100 to 10,000 volts, for example, increases the frequencies tenfold, and reduces the percentage spread of mass lines (due to velocity spread in the ion sources) by a factor of one hundred.

The first successful radio-frequency mass spectrometer, a single-stage six-electrode tube, consists of a cathode about which are arranged four co-axial cylindrical grids and an ion-collecting plate. Helmholtz coils surrounding the tube provide a 100-gauss magnetic field in a direction parallel with the axis of the tube. Such a field is required in negative-ion work to confine the electrons to the space inside the first grid and to avoid the formation of positive ions in parts of the tube where the negative ions may be neutralized before they reach the detecting electrode.

In the operation of the single-stage negative-ion spectrometer tube, ions arising at the cathode are accelerated through the first grid at a velocity corresponding to the d-c. potential of that grid (say 15 volts). They are further accelerated by the field due to the potential on the second grid which is an alternating radio frequency (say 5 volts) plus a d-c. potential (reduced to 10 volts). The third grid is held at a d-c. potential (reduced to 5 volts). Those ions which pass the first grid at the proper phase of the r-f. field, and which have a mass and related velocity such that they pass through the second grid while the r-f. potential changes phase, receive an additional acceleration due to the r-f. field while travelling to the third grid. It was found experimentally, verifying theoretical calculation, that ions passing the first grid at 45° 27.5′ of phase angle of the alternating current on the second grid, and having just the right mass (and corresponding velocity) to pass the second grid at 180° of phase angle of the current on that grid, will pass each of the first three grids with the same velocity (corresponding to 15 volts), although the d-c. potentials on those grids are successfuly reduced. This is caused by the ion picking up energy from the field of the alternating current on the second grid since the change in phase occurs as the ion passes through this grid.

A blocking potential difference, nearly equal to the maximum energy which an ion with the proper mass (corresponding to the frequency) could pick up from the alternating current, is applied between the cathode and the fourth grid. The blocking potential may be, for example, 9.6 volts negative with respect to the cathode. The collecting electrode, or ion-collection plate, is held at 40 volts positive with respect to the cathode to insure that no positive ions will reach the anode. An electrometer tube circuit and galvanometer are used for measuring the selected ion currents to the anode. An a-c. potential of 5 volts may be used while d-c. potentials of less than 100 volts are applied to the other electrodes. The required frequency range extends from 3300 kc. for a mass value of ¼ to 104 kc. for mass value 250. This range of readily-producible radio frequencies more than covers the full mass range of all elements.

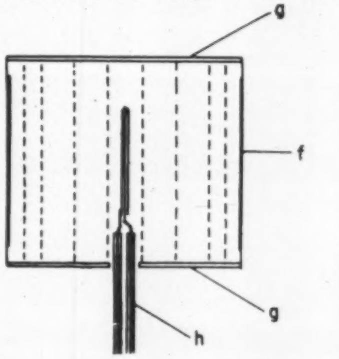


Fig. 5. Schematic diagram of the first successful r-f. mass spectrometer. This single-stage, six-electrode tube consists of a cathode, *a*, about which are arranged four co-axial cylindrical grids (*b*, *c*, *d*, *e*) and an ion-collecting plate, *f*. The electrodes are closed at the ends with mica disks (*g*, *g*) except for the hole in the lower disk through which the glass-insulated cathode lead, *h*, extends. By surrounding the tube with Helmholtz coils, a magnetic field may be provided for negative-ion work.

By extending the method to three stages in a twelve-electrode tube, either with cylindrical or parallel-plane electrodes, and applying the r-f. to three of the grids, a high order of mass resolution is obtained. Such a large number of grids would not be practical in a tube if the usual woven-wire screens were used. There is available now, however, a knitted wire fabric which has more than 95% open area and with which this kind of tube can readily be constructed. This apparatus may be used in the mass spectrometry of positive ions and in ionization studies, as well as in the present negative-ion investigations. The magnetic field is again applied in a direction parallel with the planes of the grids for negative-ion investigations. A collimating electrode containing the cathode is used to direct the ions in a direction approximately normal to the planes of the grids.

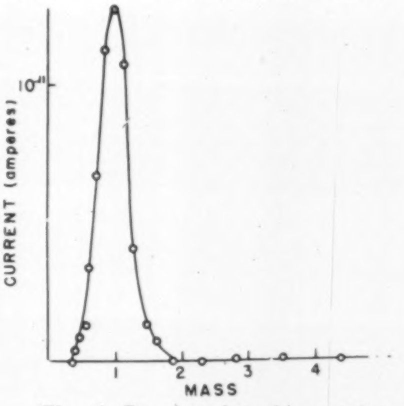


Fig. 6. By observing the negative atomic ions produced at an oxide-coated cathode in a water-vapor atmosphere at less than 10^{-6} mm. of mercury pressure, mass-resolution data were obtained at the NBS with the r-f. mass spectrometer for plotting this resolution curve.

In the positive-ion mass-spectrometer tube, the ions, accelerated toward the second grid, are resolved by the application of a radio frequency on the third grid, just as in the single-stage tube. The distance between the fourth and fifth grids is selected to assure that those ions which acquire the maximum energy from the alternating-current fields at the first stage (grids 2, 3, and 4) will travel from grid 3 to grid 6 in the time that the radio frequency takes to traverse an exactly integral number of cycles. The same r-f. is applied to the sixth grid as to the third grid and the other potentials on the second stage (grids 5, 6 and 7) are selected in a similar manner to those for the first stage. The blocking potential is applied to the anode, and the selected ions are collected there.

The simplicity and low cost of the radio-frequency mass spectrometer should make it attractive not only in those applications in which its special characteristics make it superior to any other kind of mass spectrometer, but also in those laboratories where the expense of other types of equipment is prohibitive.

New "Two-method" Phase Meter Makes Possible World-wide Navigation Systems

By E. F. FLORMAN, National Bureau of Standards, Washington 25, D. C.

An improved electronic phase meter having significant advantages over previous instruments of this type has been developed* at the National Bureau of Standards in connection with studies of radio wave propagation. The new instrument, designed for a frequency range of 100 to 5000 cycles per second, records directly the phase angle between two sinoidal voltages having a variation of 1 to 30 volts.

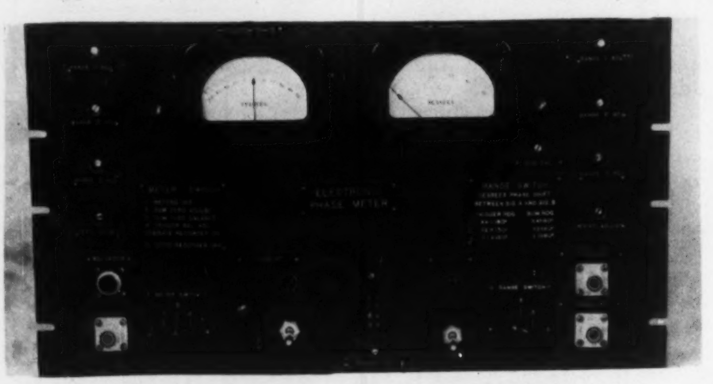
Intensive studies of low-frequency propagation paths are being made at the NBS to obtain quantitative basic information on the propagation factors which limit the ultimate attainable accuracy of any low-frequency radio navigation system. Such information should be of value in choosing a radio-navigation system for a specific purpose and, ultimately, in the choice of a practical world-wide system. In this work, differential phase changes caused by changes in the propagation medium over the paths traversed are studied by analysis of the relative phases of incoming waves received at two separate collectors. It was therefore necessary to obtain a phase meter capable of reliable results over the frequency range under investigation. It was found that available instruments of this type did not operate satisfactorily over the necessary ranges of voltages and frequencies and were rather unstable during extended periods of observation. The Bureau therefore undertook the development of an electronic phase meter for this use.

To insure stability in the receivers, as well as in the phase-measuring instrument itself, it was decided to obtain an audio-frequency beat note at each collector and to compare the phases by means of an audio-frequency phase meter. The resulting instrument has proved exceptionally stable over long periods, as well as sensitive and reliable over a wide range of voltages. It is thus well adapted to serve as standard test equipment in industrial laboratories. Other possible applications include use in electronic distance-measuring devices in surveying; altitude determination for aircraft; navigation systems depending on phase changes; studies of distortion in telephone cables; and measurement of the phase characteristics of transmission lines, filters, and transformers.

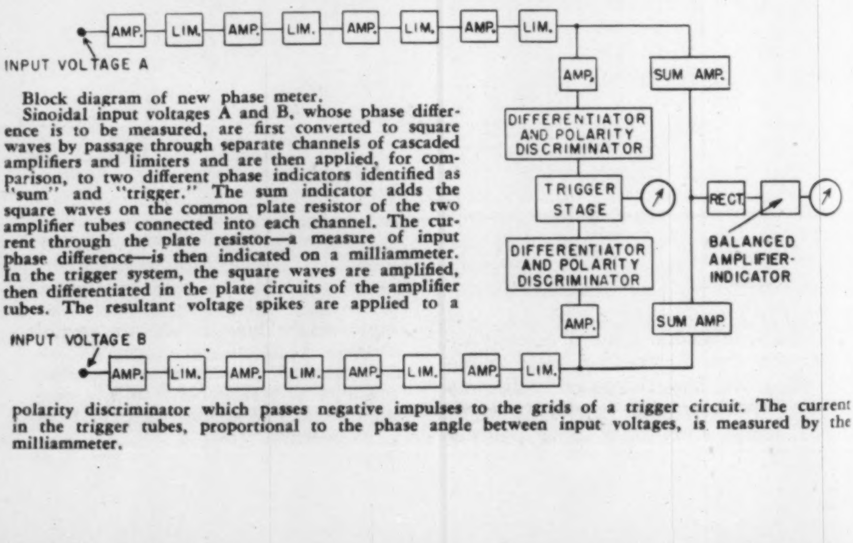
The phase meter developed at the Bureau consists of the two channels of cascaded amplifiers and limiters followed by two types of phase indicating circuits. The two indicating circuits, known as the "sum" indicator and the "trigger" indicator, are based upon different principles in order to afford a direct comparison between them.

Effectively, the sum indicator functions by measuring the algebraic sum of the square waves appearing in the similar channels. This algebraic sum is proportional to the phase angle between the input voltages but is ambiguous about the 180-degree value, that is, the same dial reading is obtained for a phase difference of 170 degrees as for a phase difference of 190 degrees. The two square waves are each applied to the grids of separate tubes having a common plate resistor. The average current through this resistor is directly proportional to the phase angle between the square waves and is therefore proportional to the phase angle between the sinoidal input voltages. This average value is obtained, by means of a diode rectifier and a balanced amplifier, on a milliammeter which serves as the phase indicator. The balanced amplifier circuit is arranged by means of proper shunts to give three ranges of phase-angle measurements: 180 to 135 or 225 degrees; 180 to 90 or 270 degrees; and 180 to 0 or 360 degrees.

In the trigger indicator system, the square waves are first applied to the grids of amplifier tubes, and the amplified square waves are then differentiated in the plate circuits of these tubes. The resultant voltage spikes, which occur at the instant of rise or fall of the square waves, are applied to a diode polarity-discriminator tube, which suppresses the positive voltage spikes and passes the negative impulses to the grids of a modified Eccles-Jordan trigger circuit. The trigger circuit is so connected that when a negative impulse is applied to the grid of one of a pair of tubes, that tube cuts off, simultaneously firing the other tube. In turn, when the second tube receives a negative pulse, it cuts off, again firing the first tube. As a result of this process, the average current flowing in the plate circuit of the trigger tubes is a measure of the time interval between voltage spikes from the two channels of the phase meter, and this time interval corresponds to the relative phase of the sinoidal input voltages. Both recording and indicating milliammeters are used with shunts to give three ranges of phase-angle measurements: 130 to 230 degrees; 80 to 280 degrees; and 0 to 360 degrees. The phase-angle readings



The improved phase meter uses two separate indicating systems: the "trigger" indicator (left); the "sum" indicator (right). (Recording instruments not shown in this view.)


AMP.
LIM.
INPUT VOLTAGE A
AMP.
SUM AMP.
DIFFERENTIATOR AND POLARITY DISCRIMINATOR
TRIGGER STAGE
RECT.
BALANCED AMPLIFIER-INDICATOR
DIFFERENTIATOR AND POLARITY DISCRIMINATOR
AMP.
SUM AMP.
INPUT VOLTAGE B

Block diagram of new phase meter.
Sinoidal input voltages A and B, whose phase difference is to be measured, are first converted to square waves by passage through separate channels of cascaded amplifiers and limiters and are then applied, for comparison, to two different phase indicators identified as "sum" and "trigger." The sum indicator adds the square waves on the common plate resistor of the two amplifier tubes connected into each channel. The current through the plate resistor—a measure of input phase difference—is then indicated on a milliammeter. In the trigger system, the square waves are amplified, then differentiated in the plate circuits of the amplifier tubes. The resultant voltage spikes are applied to a polarity discriminator which passes negative impulses to the grids of a trigger circuit. The current in the trigger tubes, proportional to the phase angle between input voltages, is measured by the milliammeter.

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*By the author and A. Tait, also of the NBS.

in the trigger indicating circuit are unambiguous, but the circuit is inherently unstable for phase angles in the neighborhood of 0 and 360 degrees, since here the order of firing of the tubes alternates irregularly. However, exact values may be obtained for phase angles in this region by the use of the sum indicator.

The new instrument reads and records phase differences with a sensitivity of 0.5 degree. In a series of tests at the NBS, the curve of phase-meter reading versus phase was found to be linear within one degree over a range of input frequencies from 100 to 5000 cycles per second. For extremely rapid changes in the amplitudes of input voltages from 1 to 20 volts, the readings showed a phase change of but one degree. Observations were independent of frequency from 100 to 5000 cps. In this frequency range, for input voltages from 2 to 15 volts, the readings varied only 0.25 degree for a line-voltage variation of 100 to 120 volts. A 72-hour stability test showed that the maximum drift after the first 15 minutes of warm-up was approximately 1.6 degrees while the maximum rate of drift was 0.25 degree per hour. Throughout the tests the sum and trigger indicators checked each other closely.

A New Rapid (millisecond) Automatic Equi-step "Staircase" Method of Calibrating Voltage-actuated Recorders

By H. L. CURTIS, National Bureau of Standards, Washington 25, D. C.

IN precision measurements of rapidly-changing voltages, it often is desirable to calibrate the recording instrument as soon as possible after the record has been completed. For example, in making a continuous record of the electric potential developed by a lightning stroke, it may be essential to calibrate the recording instrument before the arrival of the thunder since the shock of the air-wave might change the calibration. Similar considerations led to the development* of a method for calibrating cathode-ray oscillographs used to measure the ballistic phenomena of cannons, because the best results were obtained when the recorders were within 100 feet of the gun.

The instruments for measuring the pressure of the powder gases, their temperature, and the velocity and acceleration of recoil were so designed that each produced an electric potential which was related to the value of the magnitude to be measured, This potential was applied to the plates of a cathode-ray oscillograph, and the deflection was recorded on a rapidly-moving photographic film. Because the deflection was not always proportional to the applied potential, a calibration consisted in recording the deflections produced by several known voltages applied in rapid succession to the oscillograph plates, thus producing a "staircase record" of potentials.

The potential steps were obtained by having a falling weight open contacts in succession so as to introduce resistance into on electric circuit. The principle involved in the calibrator is the increase by a known amount of the current in a standard resistance so that the potential between the terminals of the resistance is likewise increased by a definite amount. The calibrator and the measuring instrument are connected in series. While the instrument is making its record, the calibrator is at zero setting, so that the record is not influenced by the calibrator. The height of the falling weight is adjusted to open the calibrator switches after the signals of the measuring instrument have become zero. Thus the "staircase" calibrating potentials are impressed on the same oscillograph plates and the deflections are registered on the photographic film within a few milliseconds after the record is completed.

The unit was designed, constructed and applied to ballistic studies by the Bureau's Interior Ballistics Laboratory. Although this instrument was developed to provide a decimal "staircase," the maximum of which is adjustable from 10 mv. to 100 mv., the principle may be applied to calibrators that will give any desired number of steps.

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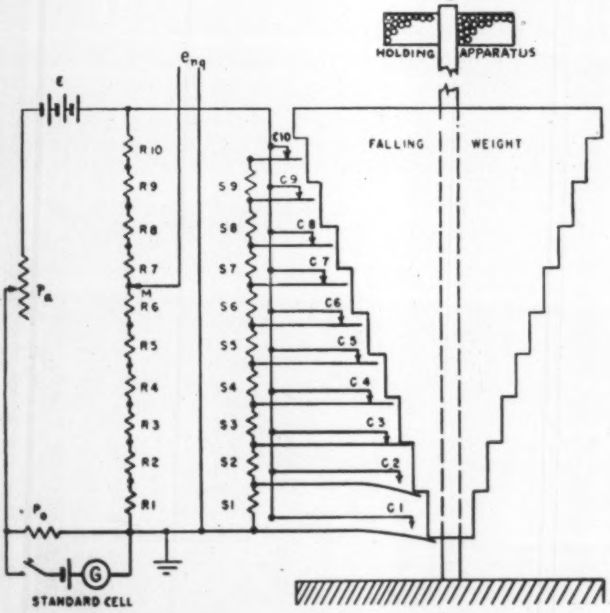
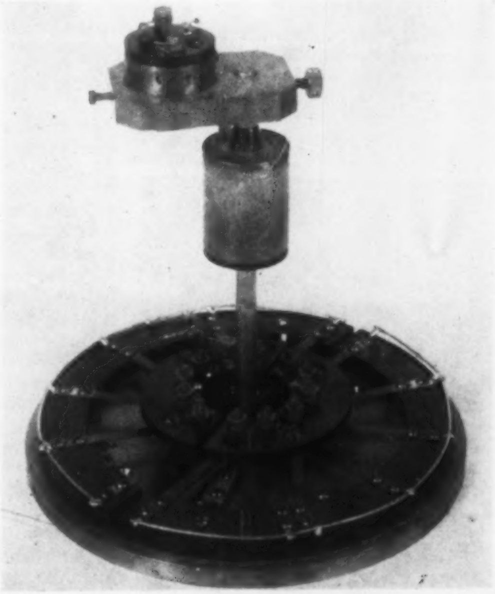
*By the author (National Bureau of Standards) and H. S. Roberts (Geophysical Laboratory).



Circuit diagram showing the principle employed by the NBS Ballistics Laboratory to produce a decimal series of potentials of equal steps. The falling weight is shown just as it is about to open the third contact. For producing (with a 4.5-volt battery) a change of one millivolt in the potential drop across each of the 10 ohm coils in the shunted resistance (coils R1 to R10), the shunt resistances in ohms are:

S1, 10.86 S3, 17.46 S5, 32.59 S7, 81.48 S9, 488.89
S2, 13.58 S4, 25.28 S6, 48.89 S8, 152.96 S10, infinity



NBS falling-weight apparatus for callibrating gun-test recording CRO's. By providing a "staircase" series of potentials in which the value of each step is known, the instrument can be used to calibrate oscillograms immediately after firing and before the arrival of the shock wave which might change the calibration. As the contacts of the automatic calibrator are opened by the falling weight, the "staircase" of calibrating potentials is impressed on the oscillograph plates, and the deflections are registered on a photographic film within a few milliseconds.

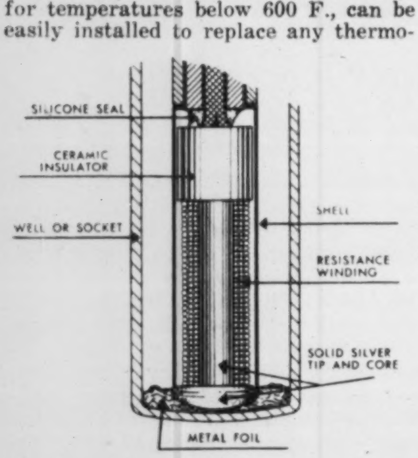
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 91

Resistance-thermometer Bulb

New "Dynatherm Resistance Bulb," for temperatures below 600 F., can be easily installed to replace any thermocouple or filled-system bulb in a well of 0.25-in. diameter or more. Heat transfer to sensitive portion being through tip (instead of sidewalls), fast response is obtained, in addition to well-known advantages of resistance method over other methods of temperature measurement.—*The Foxboro Co., Foxboro, Mass.*



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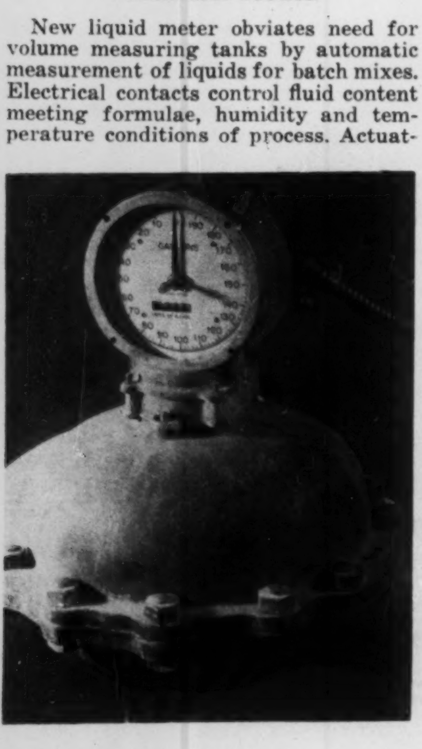
Automatic Intermittent Volumeter-feeder

New liquid meter obviates need for volume measuring tanks by automatic measurement of liquids for batch mixes. Electrical contacts control fluid content meeting formulae, humidity and temperature conditions of process. Actuating a solenoid-controlled valve, meter accurately regulates amount of liquid in given batch by shutting off valve when predetermined amount of fluid has been provided. Time is saved over the measuring tank process since meter computes liquid amount in less time than tank can be filled. Meter is designed for use in chemical, cement, food and similar industries using non-corrosive liquids.—*Buffalo Meter Co., 2906 Main St., Buffalo, N. Y.*



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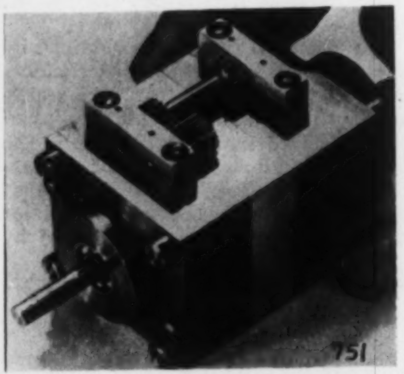
Instrument Servomechanisms

New series of small servomechanisms characterized by milliseconds time lags and quarter-degree angular deadzones (hence applicable to most exacting instrumentation requirements) is announced. Numerous combinations of components are possible. Standardized component, available "off the shelf," is electromechanical "Model 183-1" reversing clutch-brake-type servo unit (illustrated) with continuously-rotating 0.01-hp. motor, which has a torque-to-inertia ratio, expressed as acceleration, of about 4000 rpm. per second, hence better than that of low-inertia induction motors of equivalent torque output and about equal to best available low-inertia motors of much lower output. Input is supplied to side gearing (allowing convenient stacking of several servos from one input shaft); output is taken from center shaft. Clutches operate on 24 volts d.c. but motors are available to operate on any of several a-c. voltages, frequencies, phases, or on various d-c. voltages. Control circuits may be any to suit user: simple on-off contacts, or synchro systems. or electronic bridge circuits, etc. Company can supply electrical and electronic components to make up complete "packaged" servomechanisms to meet special requirements.—*Buehler & Co., 1607 Howard St., Chicago 26, Ill.*



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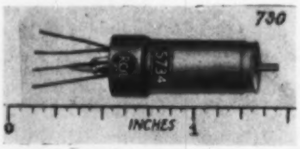
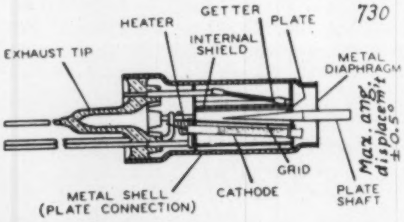
Mechanical-displacement-input Electron Tube

New "5734" is quantity-production (and improved) model of "Vibrotron" first fully described in *Instruments*, July 1946, page 420. Sensitivity is 20 volts per half-degree deflection of protruding 0.04-inch-diam. "shaft" and vibrations up to 12,000 cps. can be measured. New transducer weighs 1.75 grams (0.062 oz.).—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*





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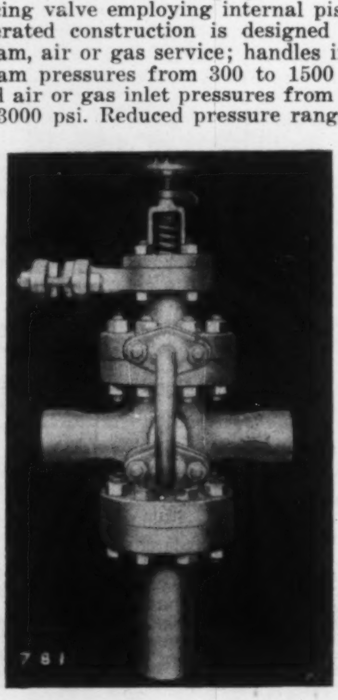
Pressure-reducing Valve

New "Class HS" high-pressure reducing valve employing internal piston operated construction is designed for steam, air or gas service; handles inlet steam pressures from 300 to 1500 psi and air or gas inlet pressures from 300 to 3000 psi. Reduced pressure range is

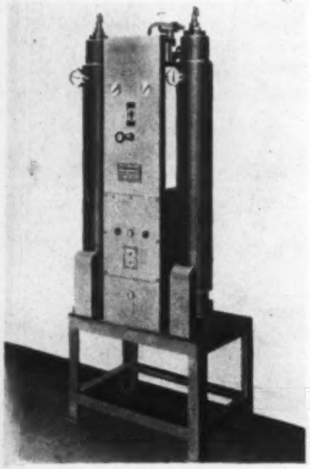


from 100 psi to 600 psi. Maximum inlet temperature is 1000 F. Construction: cast chrome moly steel body with integral Stellited seating surface. Available in sizes 1 to 2 in. with Series 90 or 150 flanges or welding ends. Interchangeability of replacement parts makes possible complete overhaul without removal of the main body from the pipe line.—*Leslie Co., 225 Delafield Avenue, Lyndhurst, N. J.*

Please mention number 105 when filling out card

Automatic Compressed-air Dryers

New line of automatic compressed air dryers comprises nine standard models with capacities from 15 to 750 cfm. (STP) based on conditions of 100 lbs. pressure and 70°F. Operating pressures can be from 30 to 150 lbs. or 40° to 120°F. inlet temperatures and final exit dew points as low as −60°F. Drying towers are all ASME. Models can be furnished for either electric or steam operation.—*The Anders Co., 420 Lexington Ave., New York 17, N. Y.*



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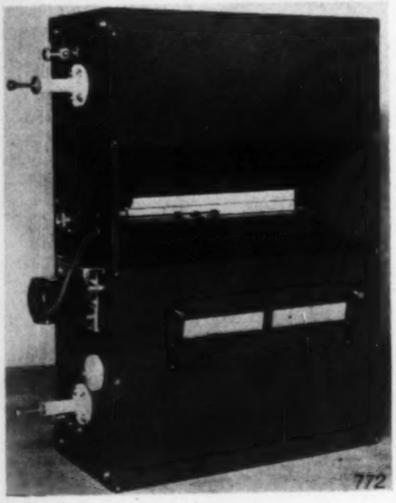
Photographic Tape Recorder

New photographic tape recorder, especially designed for recording a channel system of reflecting galvanometers can be supplied with any combination of uniform paper speeds. Stock paper spools holds 300 ft. of photographic paper 12 in. wide. Outside dimensions of case are 24 × 16 × 8 in. —*W. F. Sprengnether Instrument Co., 4567 Swan Ave., St. Louis 10, Mo.*



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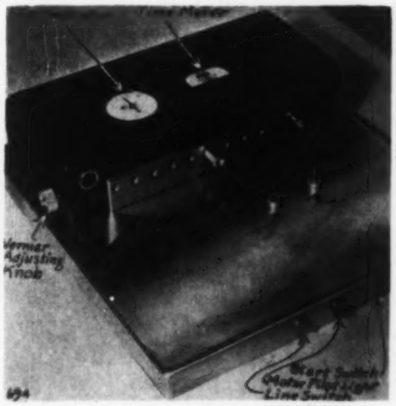
Temperature and Pressure Recorders

New models of temperature and pressure recorders are available with 1, 2, 3 or 4 pens and provide for easy field installation of actuating system and pen mechanism. Temperature tube systems feature an all stainless steel, heli-arc welded construction with improved design of spiral spring. Standard bulb design is arranged so that it can be converted into any of usual apparatus connections.—*Penn Industrial Instrument Corp., 3116 North 17th St., Philadelphia 32, Pa.*

Please mention number 108 when filling out card

Wire Fatigue Testing Machine

New rotating-beam fatigue testing machine is said to provide data accurate within 1%, with greater speed than heretofore obtainable. Instrument permits applications of fatigue knowledge to (1) control charting of wire-drawing processes, (2) wire acceptance on basis of statistical analyses, (3) studying variations throughout wire lot, (4) research, (5) predicting wire life. Sample of predetermined length is looped through 180° so that bending stress (at peak of the loop) can be predicted, simply calculated and brought to as great a value as desired in order to hasten specimen failure. Instrument is adaptable to wire from 0.005″ to 0.030″ in diameter. Instrument consists of motor-driven chuck (3600 rpm) and bushings to position end of sample not clamped in chuck. Bushing can be positioned with vernier accuracy to 0.001″. Two supporting guides mounted on "Alnico" magnets hold specimen in horizontal plane, prevent vibration, and can be quickly positioned anywhere on steel apron of the instrument. Revolutions of synchronous motor are accurately counted by "Telechron" timer read in tenths of minute. Test is automatically terminated as specimen breaks and stops motor and timer. Instrument is $17' \times 18\frac{13}{16}'' \times 5\frac{3}{16}''$.—*Apparatus Div., Hunter Spring Co., Lansdale, Pa.*



Please mention number 109 when filling out card

Resistance-thermometer Assemblies

New fused-in-glass copper resistance thermometer assemblies are announced. Manufacturer states that copper is desirable for several reasons: obtained in great purity and of uniform and reproducible quality; coefficient is high and remains constant between 0 and 200 C. Manufacturer claims to have succeeded in processing units in such a way that coefficient is reproducible. Therefore, new units are suitable for use as standards between 0 and 200 C. without calibration. Units are 3.5 in. long, 0.2 in. O.D. and are fitted with 2, 3, or 4 leads. Immersion length is 2.5 in. Units can be operated to 600 F. Characteristic time is 3.2 seconds for 63% change.—*Paul G. Weiller, 25 Broad St., New York 4, N. Y.*

Please mention number 110 when filling out card

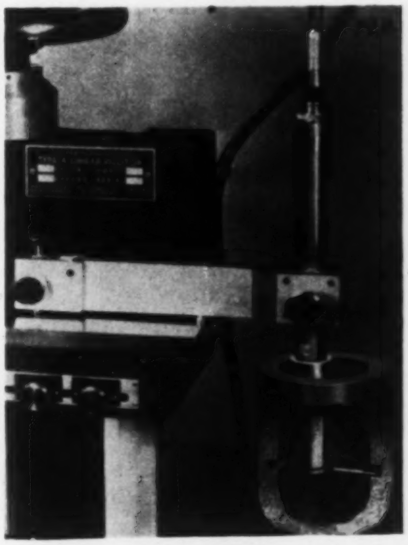
Thermocouple Assembly

New thermocouple assembly, said to minimize replacement costs, is recommended for all heat-treating services including neutral salt baths but excluding sulphurous atmospheres (for which chrome-nickel protective tubes are required). Assembly includes No. 8 gage standard heat-resistant Chromel-Alumel element for use with any pyrometer. "Inconel" protecting tube (0.875-in. OD) fits thermoelements closely, insuring sensitivity and response. Easily-replaced thermocouples can be inspected without disconnecting leads. Ceramic connector body withstands high temperatures. — *Arklay S. Richards Co., Inc., 52 Winchester St., Newton Highlands 61, Mass.*

Please mention number 111 when filling out card

Tracer for Internal-surface Roughness Recorder

New "Type GB Tracer," for use with all "Profilometer Amplimeters" in taking surface roughness measurements on



hard-to-reach surfaces, provides for measuring on internal grooves and slots; tracing axially in small holes; tracing both transversely and longitudinally in narrow slots and grooves and on gear teeth; and tracing on internal and external tapered surfaces. It is designed to be operated mechanically by maker's "Pilotor" (see illustration). —*Physicists Research Co., 321 S. Main St., Ann Arbor, Mich.*

Please mention number 112 when filling out card

Vibration Meter

New vibration meter reads vibration levels directly in rms. inches or rms. inches per second when used with maker's velocity pick-up. Unit is self-contained, battery-operated, with internal calibration requiring no external power connection. Integration of velocity pick-up signal to provide displacement measurements directly is effected by throwing switch; no scale factor or conversion is required. Range from 0.001 to 50 in. per second; 0.001 in. up for displacement. Weight, 14 lbs.—*The Calidyne Co., 751 Main St., Winchester, Mass.*

743

Please mention number 113 when filling out card

Vibration Recorder

New model of "Vibrograph," like original model (see March 1942 issue, pages 83-87, 94) embosses permanent record of vibrations on a transparent film. Frequency range 600 to 15,000 cpm.; amplitude range 0.0001 in. to 0.0625 in. Instrument incorporates seismic pendulum support whose natural frequency is lower than frequency of vibration to be measured, thus tends to remain stationary in space of triangular arm supported from vertical column by means of frictionless elastic hinges. Low natural frequency is attained by mounting "Vibrograph" relatively close to hinges and setting large mass in pan at free end of arm. "Vibrograph" includes a prod adapted to contact structure whose vibration is to be measured. —*Barry Corp., Cambridge, Mass.* and *Westinghouse Electric Corp., Baltimore, Md.*

Please mention number 114 when filling out card

Combination Watthour and Thermal Watt Demand Meter

New "Type IHM-1" single-phase combination watthour and thermal watt demand meter for industrial use is slightly larger than conventional watthour meter, can be installed wherever rate structures require determination of demand as well as energy, without increasing size of original installation. Watthour unit has "I-50" damping system and electromagnet (see May 1948 issue, page 416). Thermal unit is adaptation of "HI-1" thermal meter (see May 1946 issue, page 287) with "direct heat" operating principle. — *Meter & Instrument Div., General Electric Co., 40 Federal St., West Lynn 3, Mass.*

DEMAND
KILOWATTHOURS
GENERAL ELECTRIC
SINGLE-PHASE WATTHOUR AND THERMAL WATT DEMAND METER
744

Please mention number 115 when filling out card

Radio Remote-control Unit

New "Type EC-8-A" remote control unit meets new FCC rules and makes it possible to install transmitters and receivers in good radio-coverage areas where they can be controlled from convenient dispatching points. Capable of turning on plate power at transmitter or mute a particular combination of station receivers, "EC-8-A" employs automatic level control preamplifier to modulate transmitter and to maintain maximum allowable signal. Equipped with push buttons, positive indicator lights, and illuminated meters. Two separately controlled inputs to line amplifier circuit include one for station receiver monitoring, another for monitoring auxiliary receivers. Unit is 20 in. wide, 10 in. high, and 14 in. deep, and may be rack mounted.— *Radio Communications Section, General Electric Co., Electronics Park, Syracuse, N. Y.*

Please mention number 116 when filling out card

One-inch Electrical Instruments

One one-inch electrical indicating instruments have a 270-degree scale-arc, claimed to give a greater scale length than 3.5-inch conventional instruments. Accuracy is 2 percent. Instruments withstand vibrations and shocks; can be made watertight; are mounted by means of threaded ring which permits sealing to panel.—*International Instruments, Inc., 331 East St., New Haven 11, Conn.*

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Please mention number 117 when filling out card

Air-stream Probe Actuators

New actuators are designed for remote positioning and indicating of probes used in air streams. System consists of actuator, electrical indicator and control box. It permits personnel to read and operate probe position from control room in safety. Motors require 24 volts d.c. or a.c. Indicator operates on 110 volts a.c. Overall accuracy can be secured to 0.001 in. on traverse and 0.10 deg. on angle. Actuators can be obtained in various sizes: 4 in. to 20 in. traverse and 180 deg. to 360 deg. angular survey. One remote position indicator may be used with one to six actuators.—*L. C. Smith and Co., Enterprises, 115 Hartman St., Berea, Ohio.*

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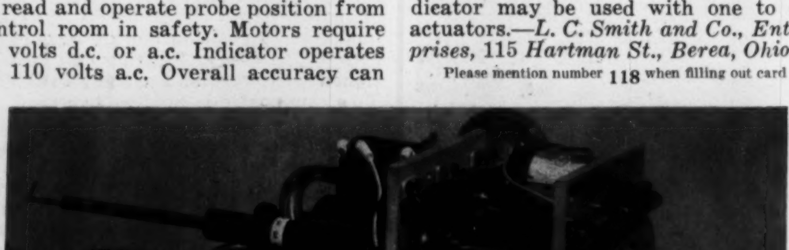


Aircraft Navigation System

New "Omnimatic" aircraft navigational system comprises VHF receiver, VHF transmitter, power supply, and "Omniscope"—all weighing about 24 lbs. Said to be first such system practical for privately-owned planes, it provides instant, automatic bearing indications when receiver is tuned to one of new "Omni-Range" stations now replacing present low- and high-frequency radio ranges. Receiver features continuous tuning through 108 to 127 Mc. band. 3-in. oscilloscope is calibrated in degrees azimuth. System is adaptable for instrument landings.—*Lear, Inc., Grand Rapids, Mich.*

Please mention number 119 when filling out card

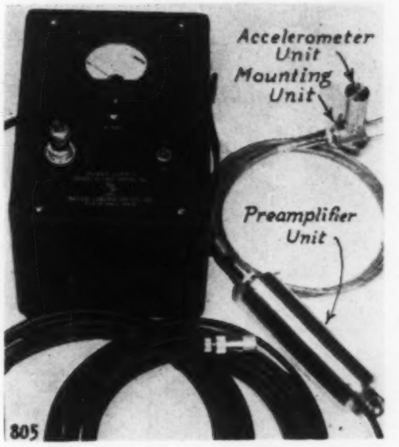
Electric Motor-control System

New "Type H1 Thy-mo-trol" drive (shown with cover removed) is available from stock in ratings through 0.5 hp.; utilizes a simplified half-wave circuit to provide d-c. flexibility from a-c. power. Turn of knob at single control station provides stepless speed control on small lathes, pumps, etc.—*Control Div., General Electric Co., Schnectady 5, N. Y.*

Please mention number 120 when filling out card

Vibration-measurement Equipment

New "Model GA-1006" vibration measurement equipment was fully described in technical article "A New Method of Vibration Measurements for the Frequency Range 20 to 20,000 Cps." in our November 1948 issue, pages 1012-1014. New extremely-rugged accelerometer unit gives a uniform electrical output for constant acceleration throughout range of 10 cycles to 20 kc. per second. Its output is linearly proportional to mechanical vibrations corresponding to accelerations ranging from less than 0.001 G to more than 100 G. It responds only to vibrations applied along its principal axis and can therefore be used to measure absolute vector components. New equipment can also be used as a wide-range sound pressure measuring instrument for conventional (low-level) measurements as well as for making blast-wave analyses of gunfire, explosions, etc.—*Massa Labs., Inc.*, 3868 *Carnegie Ave., Cleveland* 15, *Ohio.*



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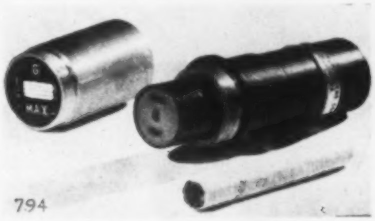
Abrasion Testing Set

New "Model 100-109" abrasion testing set provides rotary abrading action on 4-in. specimen, alternately rubbing flat faces of two resilient "Calibrase" wheels over surface being tested. New features include improved suction pump with vertical dust receiver, adjustable timer, switches providing any combination of operating conditions, such as with or without vacuum pick-up, continuous operation without timer or any timing up to 15 minutes. Three sets are offered, each complete with parts and supplies for various types of testing. — *Dept. I, Taber Instrument Corp.*, 111 *Goundry St., North Tonawanda, N. Y.*

Please mention number 122 when filling out card

Aircraft Accelerometers

Two new aircraft instruments are said to make available "for the first time a means of indicating or recording excessive G-loads under all types of flight conditions." (1) New "G-Warning Indicator" (shown on the right) flashes a warning light when aircraft approaches design load limit. Light is designed to eliminate effects of direct sun glare; serves as an immediately perceptible visual warning at all times. (2) New "G-Max Indicator" (left) provides a record of maximum acceleration; can readily be reset to zero, although, if desired, setting device can be sealed to prevent tampering. ". . . For the first time a means of determining the g-loads encountered during any period of operation." Standard instrument records in range of 3-7 G's; special models for any desired range. Both instruments are panel mounted and occupy a space of one inch. Speed of response and degree of damping are such as to provide accurate indication of gust loads as well as G-loads during maneuvers. — *Flight Research Engineering Corp., Richmond* 1, *Virginia.*

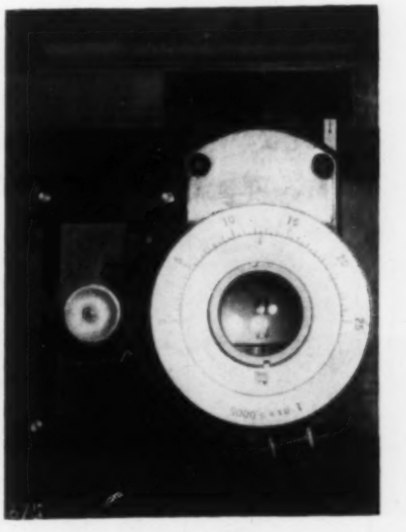


Please mention number 123 when filling out card

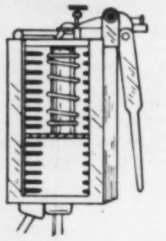
Machine-tool Movement Micrometer

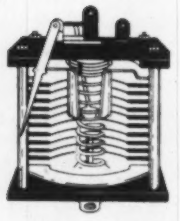
New "Scan-a-scale" linear measuring device is said to provide superior method of controlling table and spindle movements on manufacturing or tool room machines. It is intended to be used in conjunction with standard reference scale or it can be supplied with scale as a complete measuring unit for attachment at a manufacturing plant. Device consists essentially of microscope fitted with moving reticle screen

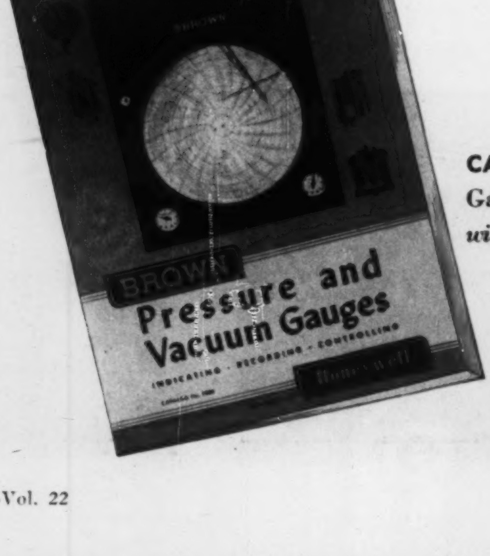
Continued on page 48



Here's where to start for



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Pressure and Vacuum Gauges
INDICATING · RECORDING · CONTROLLING
Honeywell

CATALOG 7000, "Brown Pressure and Vacuum Gauges," *is complete and informative. A copy will be sent to you upon request. Write today!*

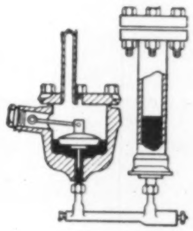
PRECISE PRESSURE CONTROL

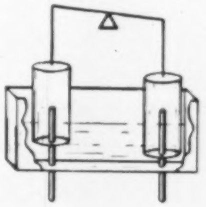
These measuring elements are the heart of Brown pressure control systems for better processing . . . because precision control starts with precise measurement!

Complete coverage of pressure problems necessitates this complete line of elements.

There's a specific one for each application . . . from microns to tons . . . from corrosive to non-corrosive! They make Brown Pressure Gauges *the finest available to industry.*

You'll find detailed information in Catalog 7000 . . . send for it today.





MINNEAPOLIS-HONEYWELL REGULATOR CO.

BROWN INSTRUMENTS DIVISION

4482 Wayne Ave., Philadelphia 44, Pa.

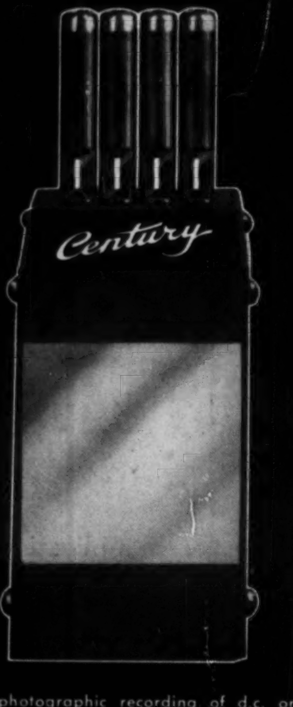
Offices in principal cities of the United States, Canada and throughout the world

BROWN *Advanced Instrumentation* **FOR BETTER PROCESSING**

Product of MINNEAPOLIS **Honeywell**

Century

RECORDING
GALVANOMETERS



For photographic recording of d.c. or a.c. currents with "flat" frequency response to as high as 2500 cycles per second. Available in a wide range of natural frequencies, all having high factors of sensitivity and dynamic balance. Their tubular hermetically sealed construction insures long-lived dependability and ruggedness. Magnetic assemblies are constructed for 2, 4, 8, 12 and 14 element mounting.

Century also offers a complete repair service on all types and makes of oscillograph galvanometers. Recent expansion of facilities makes possible immediate service.

Manufactured under Century Pat. 2439576, also licensed by Kannestine Laboratories Patent 2149442.

Century

CENTURY GEOPHYSICAL
CORPORATION

Tulsa, Oklahoma

NEW YORK
149 Broadway

HOUSTON
Niels-Esperson Bldg.

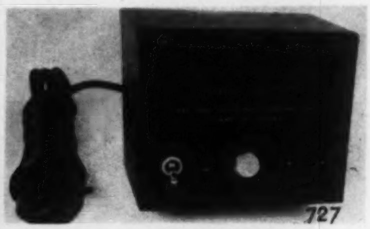
World's Largest Manufacturer of Geophysical and Special Galvanometers

controlled by graduated dial permitting table setting to within 0.0002". System of lenses causes graduations of reference scale to be clearly visible at normal eye distance (approximately 12"). There is no need for operator to place his eye close to viewing glass. Illustration shows "Scan-a-scale" mounted in conjunction with standard vernier type scale as fitted to tables and cross slides of many machine tools now in use.—*F. T. Griswold Mfg. Co., Lancaster Ave., Wayne, Pa.*

Please mention number 124 when filling out card

D-c. Power Supply

New d-c. power supply with output voltage regulation better than 1 percent and ripple less than 0.01 percent is adjusted by manufacturer for optimum regulation at any specified load from 5 to 30 milliamperes and for any output voltage from 0 to 100 volts. Regulation is thus obtained within 0.1 percent for input line voltages varying from 75 to 135 volts a.c. at frequencies from 50 to 400 cps. Unit pictured measures 4 × 5 × 6 inches and weighs 6 lbs. Other units for output voltages above 100 volts d.c.; for operation from other current supplies; and with non-standard chassis construction, available on special order. —*Hastings Instrument Co., Inc., P. O. Box* 1275, *Hampton, Va.*



727

Please mention number 125 when filling out card

Beta-gamma Scaler

New "Model K-280 Beta-gamma Scaler," developed for precise measurement of beta particles and gamma rays, may be used for research work, assaying of metals, and many other research or routine counting jobs. Among features: Highinbotham circuit, scale of 256, scale selector, autocount and autotime units. Resolving times, 5 microseconds or better.—*Instrument Div., Dept. B, Kelley-Koett Mfg. Co., Covington, Kentucky.*

735

Please mention number 126 when filling out card

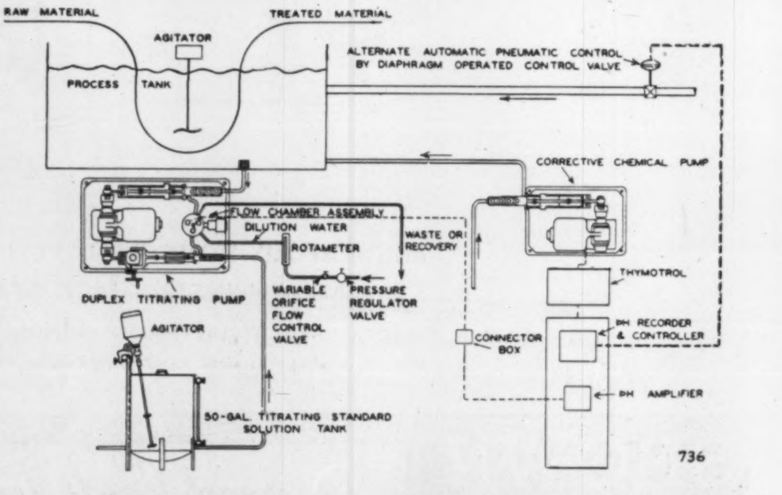
Chrome Plug Gages

New "DuBo" plug gages with hard chrome plating on gaging surfaces are claimed to outlast standard steel cylindrical plugs more than 8 times. In contrast to cylindrical plug gages, "DuBo's" give their indication when member is entered into bore with its spherical gaging surfaces out of range of bore walls and following entry gaging surfaces are rocked into contact, or potential contact, with inside of bore. Available in standard accuracy classifications including as fine as XX. Weight is approx. 20 percent of that of cylindrical plugs.—*Standard Gage Co., Inc., Poughkeepsie, N. Y.*

Please mention number 127 when filling out card

Automatic Titrating System

New "Titronic" System controls strength of caustic or acid bath automatically, is especially applicable to processes where there is relatively little change in conductivity, pH or other variable lending itself to a conventional control system. It utilizes duplex controlled-volume pump to automatically titrate sample continuously from caustic or acid bath; handles sample from bath on one side of pump and meters to that sample in direct ratio and exact proportion a fixed quantity of titrating medium; measures pH automatically and sets feed of caustic or acid to maintain desired standard in bath.—*Milton Roy Co., Philadelphia* 18, *Pa.*

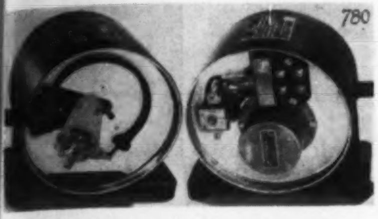


736

Please mention number 128 when filling out card

Electrical Pressure Transmitter

New "Microsen Pressure Transmitter" converts motion of tip of Bourdon tube into a directly proportional d-c. signal which can be indicated or recorded with milliampere or millivolt instruments with uniformly-graduated scales. Power consumption is 2 watts. Case construction permits servicing either pressure system or electrical system independently of each other. Ranges up to 50,000 psi. are available. Combined resistance of lead wire and indicator circuit may be up to 3000 ohms without affecting performance. Operating voltage is 115 volts at 50-60 cycles. Normal voltage variations do not materially influence final readings.—*Manning, Maxwell and Moore, Inc.*, 11 *Elias Street, Bridgeport, Conn.*



Please mention number 129 when filling out card

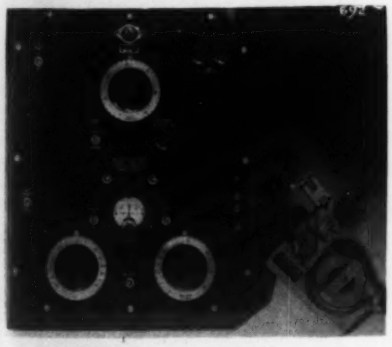
Instrument-shop Tools

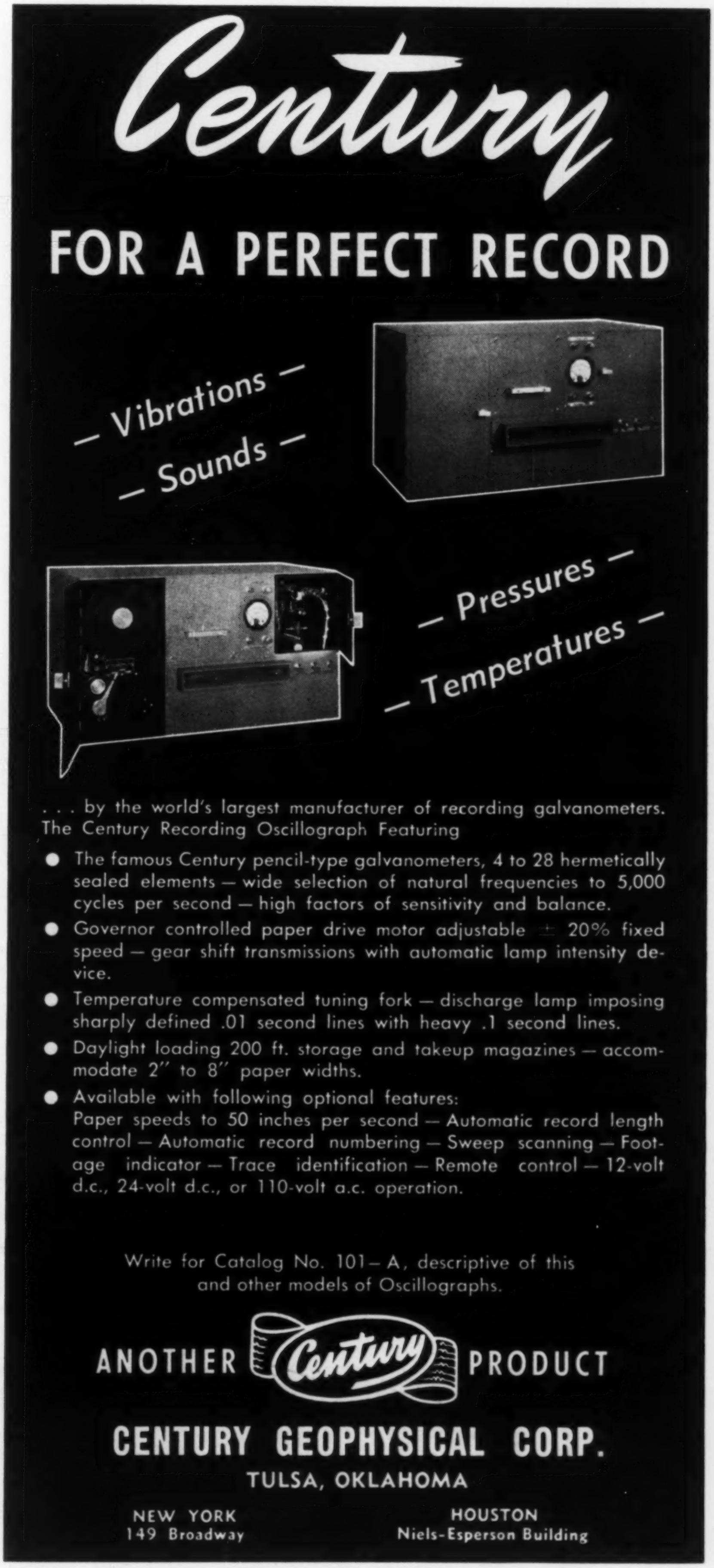
New "Grip-Slide" tools aid in cutting true finished threads, using standard American, British or Metric dies. Die or tap fits into sliding holder of tool which is held in the hand so that lathe itself turns workpiece one way against cutting tool to cut thread, and in opposite direction to back off the tool. "Grip-Slide" guide bar, inserted in tail stock, holds sliding holder (and die or tap) accurately. Advantages of tools are they can be used by inexperienced help, they minimize breakage and also are applicable for light or surface reaming, center drilling, etc.—*Threadmiller Corp.*, 44 *W. 44th St., New York 18, N. Y.*

Please mention number 130 when filling out card

Magnetic Test Set

New "Type 1760-A" test set for magnetic materials in laminar form is for measurements of permeability and core loss at 60 cycles and at low levels such as in inductors and transformers used in communication systems. Test sample can be a single lamination or a few duplicate strips in parallel. Minimum length of sample 2¼", maximum width is ⅜". Measurements are made on a





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FOR A PERFECT RECORD

— Vibrations —
— Sounds —
— Pressures —
— Temperatures —

. . . by the world's largest manufacturer of recording galvanometers. The Century Recording Oscillograph Featuring

- The famous Century pencil-type galvanometers, 4 to 28 hermetically sealed elements — wide selection of natural frequencies to 5,000 cycles per second — high factors of sensitivity and balance.
- Governor controlled paper drive motor adjustable ± 20% fixed speed — gear shift transmissions with automatic lamp intensity device.
- Temperature compensated tuning fork — discharge lamp imposing sharply defined .01 second lines with heavy .1 second lines.
- Daylight loading 200 ft. storage and takeup magazines — accommodate 2" to 8" paper widths.
- Available with following optional features:
  Paper speeds to 50 inches per second — Automatic record length control — Automatic record numbering — Sweep scanning — Footage indicator — Trace identification — Remote control — 12-volt d.c., 24-volt d.c., or 110-volt a.c. operation.

Write for Catalog No. 101—A, descriptive of this and other models of Oscillographs.

ANOTHER Century PRODUCT

CENTURY GEOPHYSICAL CORP.
TULSA, OKLAHOMA

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149 Broadway

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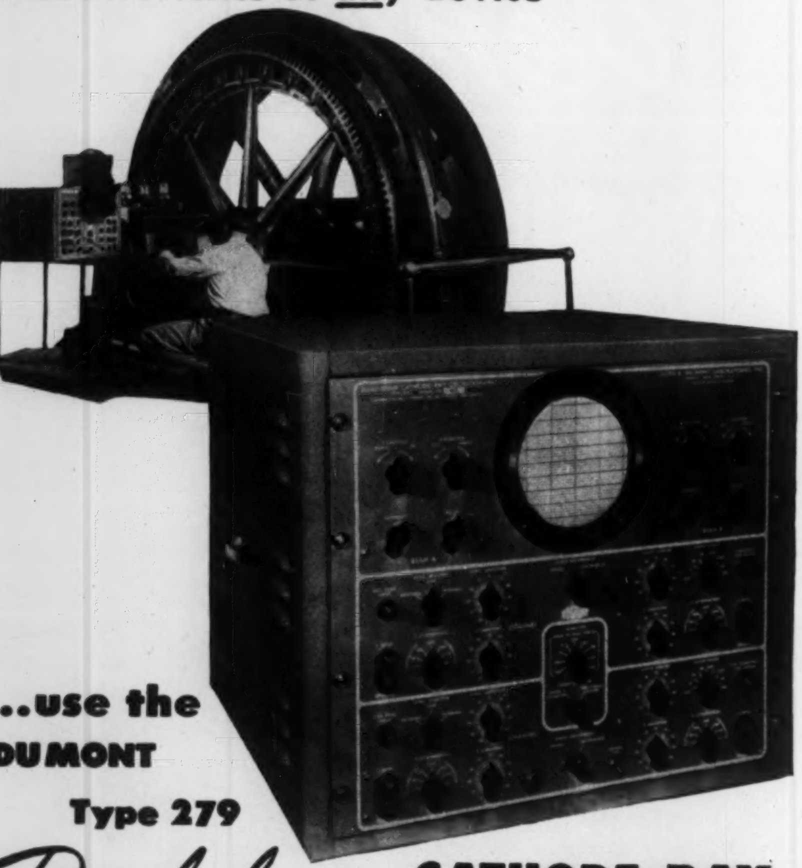
To study TWO *simultaneous* characteristics of *any* device



...use the DUMONT Type 279

Dual-beam CATHODE-RAY OSCILLOGRAPH

● Both the concomitant electrical and/or mechanical characteristics of a piece of equipment may be conveniently examined and recorded with a Du Mont Type 279 Dual-beam Cathode-ray Oscillograph.

For example: You can compare speed and vibration, velocity and acceleration, explosion time and rate of change of pressure, velocity and pressure changes on engine valves, and a multitude of other dual phenomena. Or you can examine a single phenomenon and an expanded, specific portion of it, simultaneously.

This oscillograph utilizes the dual-gun cathode-ray tube to generate and display two entirely separate and independent electron beams, which serve as inertialess, visual indicators. The circuits associated with each gun are also distinct and separate.

Where the application involves long time-intervals, the Type 279 is equipped with a d-c amplifier that is also excellent as an end stage for pre-amplifiers, such as used with strain gauges. For permanent records, Du Mont Types 271-A and/or 314 Oscillograph-record Cameras may be readily applied.

So, if your interest is petroleum research, ballistics, shock absorbers, boiler tubes, control mechanisms, timing devices, or practically any application involving two variables, be sure to investigate this Du Mont instrument.

● Consult us about the application of Du Mont Oscillography to your particular mechanical problem.
● Literature on request.

DUMONT *for Oscillography*

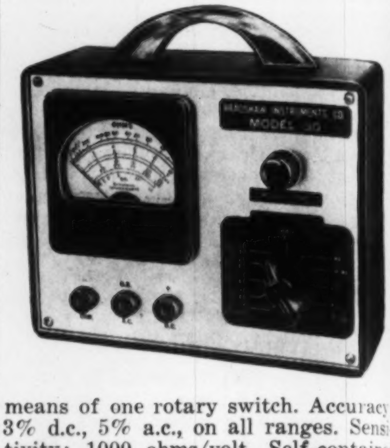
ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U. S. A.

Maxwell bridge of inductance and loss of solenoid surrounding sample. Sinusoidal magnetizing force applied to test sample is adjustable from one milli-oersted to six oersteds. A d-c. magnetizing force up to 2 oersteds can also be applied for incremental measurements. Permeability range is 25,000 full-scale for a specimen cross-section of 10 sq. mm., for which dial reads directly in permeability.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Please mention number 131 when filling out card

Multi-purpose Electrical Tester

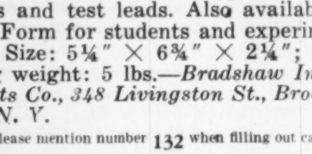
New "Multi-Tester Model 30" has a simplified method of range selection permitting all ranges to be selected by means of one rotary switch. Accuracy: 3% d.c., 5% a.c., on all ranges. Sensitivity: 1000 ohms/volt. Self-contained 4.5-volt battery. Twenty-one ranges comprise volts, amperes, milliamperes, megohms and decibels. Bench model is housed in Bakelite case with carrying handle. Portable model is housed in polished oak case with compartment for tools and test leads. Also available in Kit Form for students and experimenters. Size: 5¼" × 6¾" × 2¼"; Shipping weight: 5 lbs.—*Bradshaw Instruments Co., 348 Livingston St., Brooklyn 17, N. Y.*



Please mention number 132 when filling out card

Multi-purpose Electrical Tester

New "Servishop Model 8573" service instrument incorporates 50 ranges of instruments with complete tube tester. Maker claims it is first instrument that will test acorn tubes, miniature tubes, noval base tubes and sub-miniature tubes with the "Rollindex Roll Chart," test batteries, measure a.c. and d.c. volts, d.c. milliamperes and amperes.



ohms and megohms, decibels and output volts, test capacitators, generate AM and FM signals and incorporate an audio oscillator. More than 800 tube listings on roll chart. Germanium crystal rectifier assures a-c. measurements free from temperature and frequency errors.—*Radio City Products, Inc.*, 152 *W. 25th St., New York* 1, *N. Y.*

Please mention number 133 when filling out card

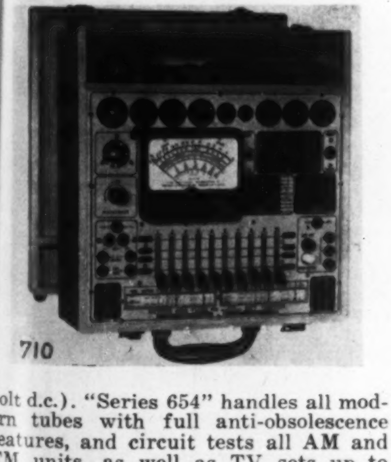
Multi-purpose Electrical Tester

New miniature tester indicates resistances from 0 to 2 megohms with accuracy of 2 percent of linear scale; d-c. voltage from 0 to 300 (accuracy 2 percent); a-c. voltage (accuracy 5 percent). Tester has toggle switch for a-c. or d-c. testing; pair of jacks into which test leads are inserted; rotary switch for selecting voltage range. All readings are indicated on single two-scale dial. Tester measures approx. 4.25 by 3 by 1.5 in., weighs 12 oz., is supplied with two "Koiled Kord" test leads terminating in pin plugs and clip leads.—*International Instruments, Inc.*, 311 *East St., New Haven* 11, *Conn.*

Please mention number 134 when filling out card

Multi-purpose Electrical Tester

New "Series 654" tester supplements maker's "600" line of test equipment. It is a combination of cathode conductance tube tester, dynamic (under-load) battery tester and high sensitivity a-c. and d-c. circuit tester (20,000 ohms-per-volt d.c.). "Series 654" handles all modern tubes with full anti-obsolescence features, and circuit tests all AM and FM units, as well as TV sets up to 30,000 volts with addition of "Series



Speedy • Accurate

RESISTANCE MEASUREMENTS

. . . with the Rubicon
PORTABLE WHEATSTONE BRIDGE

This convenient instrument combines instant portability with high accuracy and is widely used in laboratory, plant and field. Built for dependable service under hard usage.

- Wide range: 1 ohm to 10 megohms
- Limit of error: 0.1%
- Built-in battery and galvanometer
- Provision for external battery and galvanometer when required
- Available with Murray and Varley loop circuits
- Compact and rugged

. . . with the Rubicon
PORTABLE KELVIN BRIDGE

For work at very low resistance levels this instrument is the counterpart of the Wheatstone bridge shown above.

- Range: 0.0001 to 10.1 ohms
- Limit of error: 0.25%
- Built-in battery and high sensitivity "Pointerlite" galvanometer
- Provision for external battery and galvanometer when required
- Sturdy and convenient in operation

Wheatstone and Kelvin bridges in a variety of models, together with other resistance measuring instruments, are fully described in Bulletin 100 available on request.

SPOTLIGHT GALVANOMETER

- Sturdy, short period
- Sensitive (up to 0.0006 μA per mm.)
- Multiple-reflection optical system
- For null or deflection measurements

Described in Bulletin 320

•

OTHER RUBICON INSTRUMENTS

Resistance Standards • Mueller Bridges • Precision Potentiometers • Evelyn Photoelectric Colorimeter for chemical analysis • Automatic Recording Photometric Analyzers for NO and H_2S • Magnetic Permeameters • Magnetic Hardness Testers • Shorted-Turn Coil Testers • Other equipment involving precise measurement of electrical quantities.

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Electrical Instrument Makers
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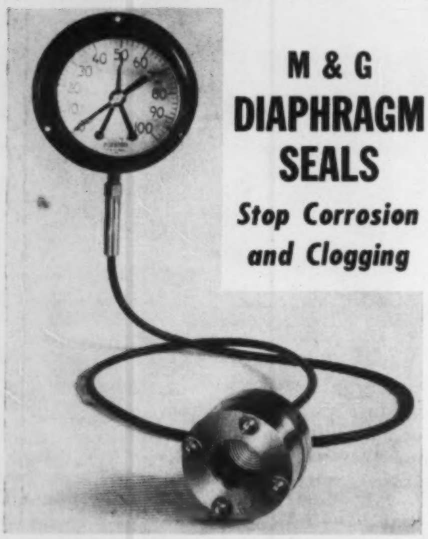
M & G Multi-Purpose

PRESSURE GAGE TESTER

- **Pressure ranges to 10,000 psi**
- **Portable or bench testing**
- **Dead weight attachments**
- **General instrument work.**



Mount on any type pressure gage, switch, or instrument.

- **Pipe Mounting ¼ to 1½ connection — plain & cleanout type.**
- **Flange type for any size pipe flange connection.**
- **Available in any machinable metal or material.**

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MANSFIELD & GREEN

1051 Power Avenue CLEVELAND 14, O.

TV-2" super-high-voltage television test probe. It requires use of only 2 pin jacks for all standard ranges; incorporates wide-angle, 4⅝", 50 microammeter, also 1% wirewound and film-type resistors. All circuits are insulated from power line for operational safety. —*Precision Apparatus Co., Inc., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Please mention number 135 when filling out card

High-power Vibrator

New "Type 1501" vibrator utilizes maker's specially developed alloy contacts. Prepared for use in conventional power supply, vibrator is applicable to FM receivers, "push-to-talk" transmitters and where power in excess of capabilities of present standard vibrators is required.—*P. R. Mallory & Co., Inc., 3050 E. Washington St., Indianapolis 6, Ind.*

Please mention number 136 when filling out card

Tape-drive Cabinet Dial for Scales

New tape-drive cabinet dial attachment for use with all types of overhead track and suspension scales incorporates new tape-drive principle, a positive-drive mechanism, using high-strength, non-corrosive special alloy tapes to replace old style rack and pinion. This development eliminates inaccuracies caused bv gear teeth wear, back-lash and friction. Tape-drive delivers smooth, positive drive to pointer and requires only minimum maintenance. Adjustable, self-compensating hydraulic dash-pot with valve-type plunger control pointer action and prevent shocks from reaching mechanism. Up to four drop-weights can be quickly put in or taken out of weighing system—*Howe Scale Co., Rutland, Vt.*

Please mention number 137 when filling out card

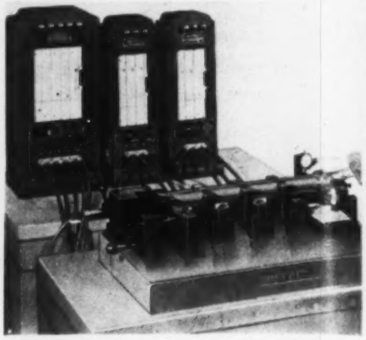
Fixed-composition Resistor

New "Type BT" insulated fixed composition resistor, available in four ratings up to 2 watts, meets Army-Navy requirements under JAN-R-11 specifications. For short periods, overloads of 50 to 100 percent may be applied without damage to resistor, and 5-second overloads of 2.5 times rated load result in only negligible resistance changes. Frequency characteristics are excellent.—*International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.*

Please mention number 138 when filling out card

Camshaft Inspection Equipment

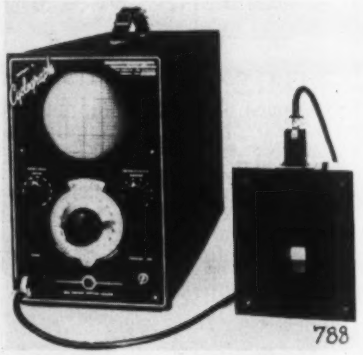
New "Camshaft Precisionaire" multiple pneumatic gage permits a complete and almost simultaneous gaging of most critical dimensions and conditions of an automobile camshaft: Six bearing diameters, two lengths of camshaft and concentricity of five bearings. Run-out of oil pump drive gear is checked by a separate gaging unit. In addition, a Sclerescope is mounted in front of front gaging station to determine hardness while camshaft is in gaging position.—*The Sheffield Corp., Dayton 1, Ohio.*



Please mention number 139 when filling out card

Metal-parts Analyzer and Classifier

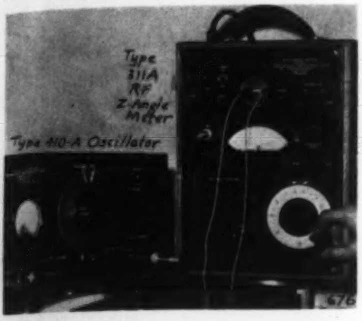
New "Model C Cyclograph" is portable, operates on core-loss principle for rapid and non-destructive metallurgical examination and sorting of metal parts. Wide range of test frequencies (2 kc. to 200 kc.) makes possible a variety of non-destructive tests: checking or sorting on basis of analysis, structure, hardness, case depth, and in some cases stress concentration. Also, in stress measurement work, it can be employed to trace internal stress changes, compare stresses at different levels, or compute stress in psi. A recorder output is provided for this use of new instrument. "Model C" weighs 50 lbs.; can be used anywhere within a plant; operates on 115 volts, 40-60 cycles. Power consumption is 70 watts. Test coil may be placed up to 12 feet from instrument.—*J. W. Dice & Co., 191 River Road, Grand View-on-Hudson, N. Y.*



Please mention number 140 when filling out card

Impedance-phase Angle Meter

New "Type 311-A R-F Z-Angle Meter" provides direct reading of impedance and phase angle at radio frequencies.

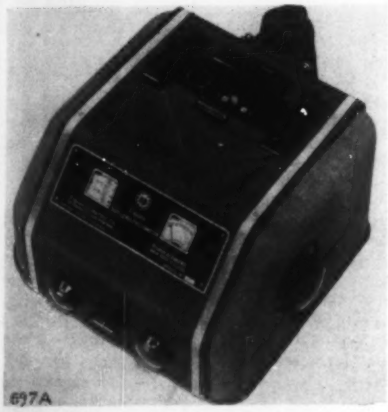


Applicable for measurements, at audio frequencies, of broadcast antennas and transmission lines, and general laboratory measurements.—*Technology Instrument Corp., 1058 Main St., Waltham 54, Mass.*

Please mention number 141 when filling out card

Multi-purpose Photometric Analytical Instrument

New "Nefluoro-Photometer" for nephelometric, fluorometric and colorimetric analyses is line-operated instrument designed to measure quantitatively, light transmitted (or absorbed), light reflected, or light emitted by sample in solution or suspension.


697A

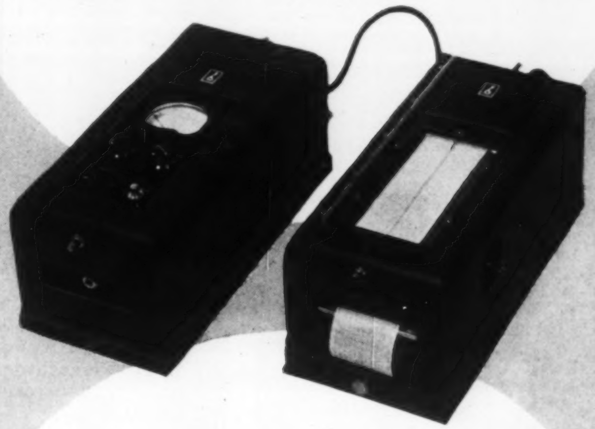
In addition to large number of analyses which can be made colorimetrically, instrument also determines nephelometrically, such as ammonia, arsenic, calcium, chlorides, silver, phosphorus, sulphur, acetone, amylase, nucleic acids, proteins, fats, oils and fatty acids. Fluorometric determinations include vitamins B_1 and B_2. "Nefluoro-Photometer" is "null" (zero balancing) instrument with built-in galvanometer. Three light sources — incandescent, mercury and sodium—operate on 115 volt 50-60 cycle a.c. Incandescent light source emits light in visible range—from about 400 to 750 millimicrons. Mercury arc source affords ultraviolet light for fluorometric work. Sodium light source has principal emission at 340 and 590 millimicrons. Three filters are specific for types of analyses possible with new instrument. Reading dial has log scale for samples that follow Beer's Law and percentage scale calibrated in 100 divi-

Would

INSTANTANEOUS

recording of electrical phenomena from D.C. to 100 c.p.s. help in your research?

It's a fact — permanent, instantaneous ink-on-paper recordings by Brush Oscillographs make their use almost unlimited!



Accurate recordings of voltages, pressures, radiation intensity and countless other phenomena can be made over a frequency range of D.C. to 100 c.p.s. Either A.C. or D.C. signals can be measured. Whenever desired, recordings may be stopped for notations on chart-paper.

Investigate *Brush* measuring devices before you buy . . . they offer more for your money. Why not have a Brush representative call? At no obligation, of course.

Just call or write — today — you'll find it worth a few seconds' time!

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THERMOCOUPLE INSULATORS

This Gordon Thermocouple Insulator, heated red hot and plunged into cold water, came out just as good as new

Available only through GORDON, Serv-rite Thermocouple Insulators are made to stand the gaff of excessive thermal shock far above normal requirements.

For sturdy and reliable thermocouple insulator performance to meet peak production needs — Specify Serv-rite...a Gordon development backed by 32 years' experience in supplying industry with insulators that last longer and give better results.

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Serv-rite Thermocouple Insulators—in any type or size—can be supplied immediately from Gordon's large stocks in the Chicago and Cleveland Plants. Remember—you can always distinguish Serv-rite Insulators by their *tan* color.

Fish Spine Beads **Asbestos String**
Asbestos Tubing **Single Hole**
Double Hole Round **Double Hole Oval**

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sions between 0 and 100%. Dial control-knob varies built-in polaroid unit, reducing intensity of illumination. Optical cell compartment accommodates different types of cells necessary for various analyses, and to shut out all external light.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.*

Please mention number 142 when filling out card

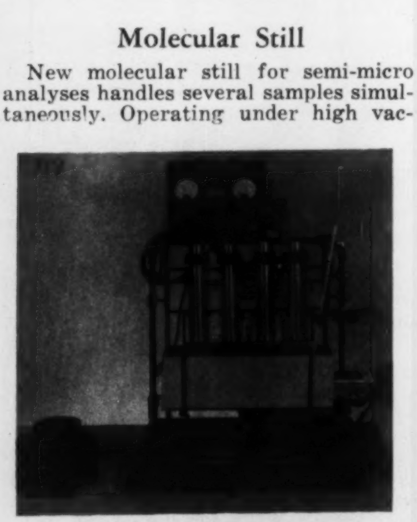
Biological Assay Instrument

New assay scanner equipment is for measuring potency of antibiotic (e.g. penicillin) by photoelectric means. Potency of antibiotic is proportional to diameter of area inhibited by antibiotic in a germ culture. This diameter is measured by recording elapsed time between selected interruptions of a light beam scanning inhibited area under study, while area is moving at constant known speed. Measurement is indicated directly in mm. Measurements accurate to 0.1 mm. are made and indicated at rate of 30 per minute. Equipment is suitable for high-speed production measurements. Developed jointly by G. C. Wilson & Co., Chatham, N. J.; Engineering Div. of Bristol-Myers Co., Hillside, N. J.; and *Control Dept. of Bristol Laboratories, Syracuse, N. Y.*

Please mention number 143 when filling out card

Molecular Still

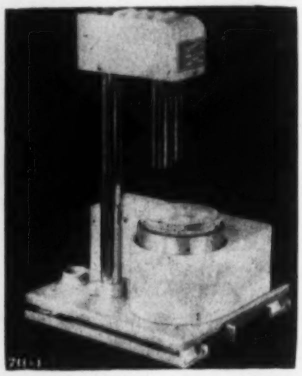
New molecular still for semi-micro analyses handles several samples simultaneously. Operating under high vacuum, new still separates heat-sensitive substances of high molecular weight. Samples are loaded into each still unit which are then immersed in oil bath held at distilling temperature by electrical heaters. Distillate collects on condenser, which is removed to obtain fraction after each distillation. Samples may range from a few milligrams to a gram in each still unit.—*Distillation Products, Inc., 755 Ridge Road, West Rochester 13, N. Y.*

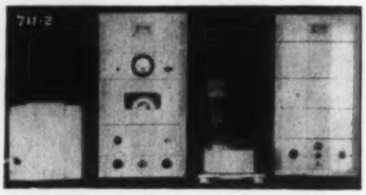


Please mention number 144 when filling out card

Biological Assay Equipment

New "Bioca" bio-colony assayer is designed to determine and record strength of antibiotic culture dilutions through measurement of their growth-inhibiting activity. In operation, petri dish in scanner head rotates for ten seconds while zones are being measured. "Bioca" is composed of four units interconnected with cables: scanner and optic system; computer rack; power supply rack; recorder. Computer and power supply racks contain several subassemblies, each mounted on a separate removable chassis. "Bioca" can be operated by one unskilled person; the only manual operation is placing petri dishes in scanner head and depressing start switch; scanning, computation and recording operations are automatic and continuous. Accuracy of readings is in the order of 0.1 mm., and 240 dishes can be processed each hour.—*Airlectron Engineering Co., P. O. Box 151, Caldwell, N. J.*





Please mention number 145 when filling out card

Oil Burner Adjusting Kit

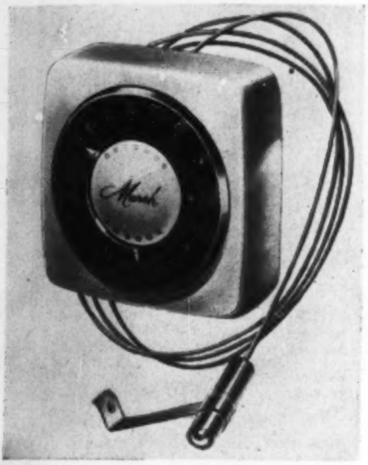
New adjusting kit for oil burning space heaters, water heaters and cooking ranges with pot-type burners in-

cludes (1) "Draftrite" draft gage, used to check up-draft in flue and adjust draft regulator; (2) New type cross test level; (3) Oil flow gage with well of clear plastic wedge-shaped and scale on flat surface, readable accurately in 0.25 cc. in the lower range, and measures up to 100 cc. (4) Two oil-collecting beakers for catching oil during oil flow test. (5) Mercury thermometer—range 0-220 F.—*Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh* 8, Pa.

Please mention number 146 when filling out card

Indoor-outdoor Thermometer

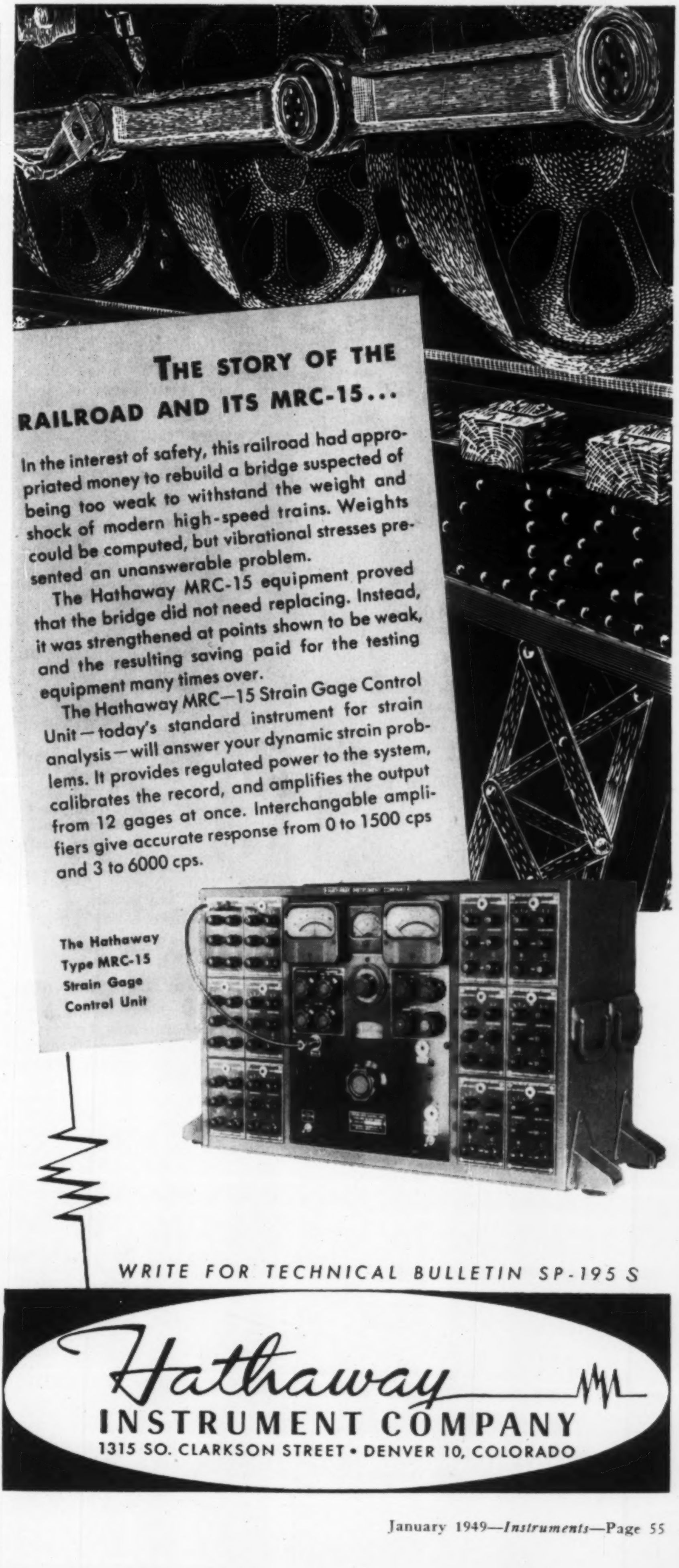
New model of "Duo-Temp" mechanical dial type indoor-outdoor thermometer has case of smoothly contoured molded plastic and gold characters which stand out on dial in sharp contrast to deep dubonnet background. Outdoor scale reads from −30° to +110°F., indoor scale from +50° to +90°F.—*Jas. P. Marsh Corp., Dept. 125-R, Skokie, Ill.*



Please mention number 147 when filling out card

Transformer Turn Ratio Test Set

New Transformer Turn Ratio Test Set is designed for use on all types and sizes of power, distribution and auto-transformers; is direct-reading; also gives an immediate indication of polarity. It consists of a multi-ratio reference transformer which is excited—by means of a small hand generator—in parallel with transformer under test. By means of four dial switches and a


THE STORY OF THE RAILROAD AND ITS MRC-15...

In the interest of safety, this railroad had appropriated money to rebuild a bridge suspected of being too weak to withstand the weight and shock of modern high-speed trains. Weights could be computed, but vibrational stresses presented an unanswerable problem.

The Hathaway MRC-15 equipment proved that the bridge did not need replacing. Instead, it was strengthened at points shown to be weak, and the resulting saving paid for the testing equipment many times over.

The Hathaway MRC—15 Strain Gage Control Unit—today's standard instrument for strain analysis—will answer your dynamic strain problems. It provides regulated power to the system, calibrates the record, and amplifies the output from 12 gages at once. Interchangable amplifiers give accurate response from 0 to 1500 cps and 3 to 6000 cps.

The Hathaway
Type MRC-15
Strain Gage
Control Unit

WRITE FOR TECHNICAL BULLETIN SP-195 S

Hathaway
INSTRUMENT COMPANY
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We maintain a complete department for repair and reconditioning all makes of thermometers. After reconditioning, instruments carry the same guarantee as the original new equipment.

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6TH & CAYUGA STREETS
PHILADELPHIA 40, PA.

null balance indicator, reference transformer is adjusted in ratio to equal that of transformer under test. The ratio is then read directly from the dial switch indexes. Ratios up to 130 can be measured with 0.1% accuracy. Set operates without burden, at low-voltage excitation and by null balance, and therefore gives a precise measurement of no-load voltage ratio. It is supplied complete with testing leads and weighs about 31 lbs. It is intended for use in shop and field.—*James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.*

Please mention number 148 when filling out card

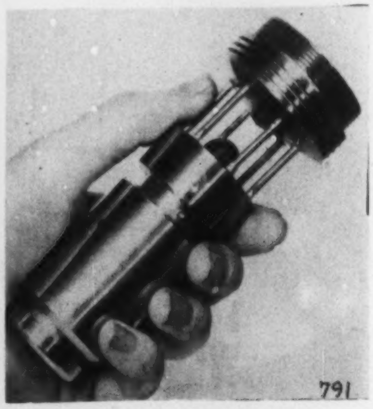
Ultra High-frequency Tube

New "Type TT-1" ultra high-frequency diode tube used to measure sensitivity of radar and television receivers and distance over which they can be seen and heard, is only 3" long and ⅜" in diameter. It supplies electrical noise for determining receiver sensitivity. Tube generates all frequencies at the same time and has upper limit of 3,000 million cycles.—*Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.*

Please mention number 149 when filling out card

Hydrostatic Impulse Gage

New mechanical self-registering gage may be lowered into a well or connected to a pressure chamber to measure directly total impulse per unit area generated by pressure waves resulting from underground explosions or other high-pressure sources. Operation: hydrostatic impulse forces mercury through a capillary passage and into a



For DELICATE Soldering Jobs . . .

NEW WELLER SOLDERING GUNS

FLEXITIP—easily formed.
LONG REACH
SOLDERLITE—spotlights the work
BUILT-IN TRANSFORMER
DUAL HEAT—Single heat 100 watts, dual heat 100/135 watts; 115 volts, 60 cycles
5 SECOND HEATING—no waiting

For light, delicate operations, where **precision** heat-control is essential—rely on your 4" Weller Soldering Gun. Pliable FLEXITIP slips easily into "ticklish" spots. **Automatic** heat—on in 5 seconds, off when you release trigger—speeds soldering, prevents burning, and enables you to adjust tip temperature to suit job. Perfect balance and handy pistol grip give comfort **and** control.

For faster, safer instrument soldering, order Weller Gun type S-107 single heat or D-207 dual heat from your dealer—or write for catalog direct.

Be Sure To Get Your Copy— SOLDERING TIPS, the new Weller Handy Guide to easier, faster soldering — 20 pages fully illustrated. Price 10c at your distributor's or order direct.

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collector; weight of mercury discharge is proportional to impulse per unit area in psi.-sec., from 10 to 400 psi. Gage is self-contained and of simple construction, for convenience in field use. Its applications include geophysics, internal combustion studies, blast damage determination, water hammer research. —*Engineering Research Associates, Inc., St. Paul 4, Minn.*

Please mention number 150 when filling out card

Purge-rate Flowmeter

New "Bubbler type" purge service flowmeter measures gas or liquid purge rates in cubic feet per hour of air or gallons per hour of water; is adaptation of maker's "Flowrator" that includes built-in needle valve for close control of purge rates. It covers range of measurement generally accepted as standard for bubbler installations. Unit consists of Pyrex or stainless steel ball-shaped float, precision-bore "Pyrex" metering tube and die-cast body which houses needle-type control valve.—*Fischer & Porter Co., Hatboro, Pa.*

690

Please mention number 151 when filling out card

Electro-mechanical Counter

New "No. 1200" electro-mechanical counter can be stacked to six digits and provide reliable carryover at an operating speed of 1200 cpm. Numerals are 0.438 in. high. Control relays permit these additional functions: electrical reset to zero in half a second; alarm at end count; electrical read-out; independent input to any digit cell; subtotaling; self-testing. Fields of application include computers, flight control

806

STRUTHERS-DUNN

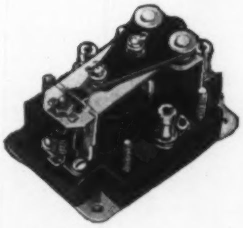
5,348

RELAY TYPES

It pays to use relays that are SPECIFICALLY TAILORED to your application
STRUTHERS-DUNN, Inc.
Data Section 2100
MIDGET RELAYS... FRAMES 1 and A58
INDEX

Yours for the asking!

A HANDY GUIDE TO small RELAYS



NEW! A MIDGET WITH 15 AMP. CONTACTS

Type 1HXX36: Only 1⅞" x 2¼" x 2" high. Underwriters' approved. SP, DB, ST normally-open ⅜" silver contacts rated 15 amps. at 115V. AC.

This bulletin makes it easy for you to select small industrial control relays with the exact contact arrangement, mounting details and construction required for each application. In concise, easily understood form, it contains complete information on standard Struthers-Dunn Midgets and includes many available adaptations to fit these to specific operating conditions. Ask for Data Section 2100.

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The *Accurate* Way to
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The Simplified PYRO Optical Pyrometer

SELF-CONTAINED. No correction charts, no accessories, no up-keep. *Direct-reading.*

ACCURATE. Permits *close* and *rapid* temp. de*termination* — even on *minute spots, fast-moving objects, smallest streams.* ("Special Foundry Type" and "Triple Range" also have RED Correction Scale for determining *true spout* and *pouring* temps. of molten iron, steel in the open.)

LIGHT IN WEIGHT — Only 3 lbs. complete. Handy.

PROVED IN USE—Foundrymen all swear by it.

Stock Ranges 1400°F. to 7500°F.

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2 & 3-DIMENSIONAL ENGRAVER

Permits accurate reproduction of three-dimensional master on any of four reduction ratios.

Catalogue on request

MICO INSTRUMENT CO.
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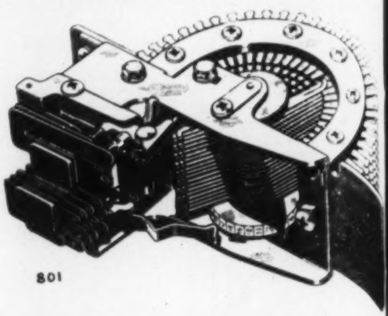
CAMBRIDGE, MASS.

boards, production control.—*Engineering Research Associates, Inc., St. Paul 4, Minnesota.*

Please mention number 152 when filling out card

Spring-driven Stepping Switch

New high-speed spring-driven stepping switch may have from one to ten bank levels, each comprising 26 contacts. A pair of double-ended wiper springs is stepped over each bank level, which occupies 180 degrees; one end of wipers is therefore always free of bank contacts; other end always in engagement. As one end leaves 26th contact, other end is approaching first contact. By stepping through 180 degrees, each end of wipers steps successively over



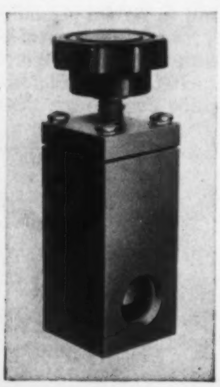
801

all contacts. Stepping magnet may be controlled or wipers may be caused to step automatically by interrupting magnet circuit. Switch may be allowed to stay put at completion of operating cycle or it may be homed, or returned to normal. In many details, it is like model descriped in Sept. 1946 issue, pages 533-534. It is for d-c. only. Remote controlled operation 30 steps per second max.; self-controlled operation averages 60 steps per second with 48-volt power supply. Weight approx. 27 oz.; length 6.562 in. — *C. P. Clare & Co., 4719 Sunnyside Ave., Jefferson Sta. Chicago, Ill.*

Please mention number 153 when filling out card

Packless Valves

New "type R" valves are 90 degrees packless, of bellows type, designed for minimum flow resistance in high-vacuum service. ¾" unit shown has provision for solder connections. Pipe thread connections are also avilable. Supplied



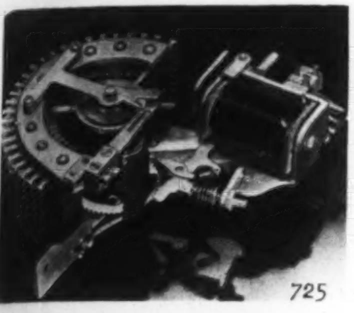
in sizes up to 3 inches. Low resistance is achieved by large lift of valve disk; multiple thread on stem reduces number of turns required for full opening. Bellows and disk assembly are remov-

able. For use in vacuum stills, vacuum coating, electron tube evacuation, test manifolds, ion and electron accelerators, etc. Also suitable for low-pressure systems where tightness is important.—*Thomas Electronic Engineering Co., 316—37th St., Brooklyn* 32, *N. Y.*

Please mention number 154 when filling out card

Automatic Stepping Switch

New "Type 45" 25-point automatic rotary stepping switch is adaptable to electrical control requirements calling for remote selection of circuits by means of either external pulsing or self-pulsing control. Switch can be provided with any number of 25-point bank contact levels up to maximum of 15, and single ended contact brushes can be supplied to provide up to 50 outlets. When equipped with 10 contact brushes, switch can be adjusted to operate at speeds up to 70 steps per second when self-pulsed, or up to 35 steps per second with external pulsing, on 46 volts d.c. Stopping teeth replace pawl stop and armature stop of older designs.—*Automatic Electric Co.*, 332 *S. Michigan Ave., Chicago* 4, *Ill.*


725

Please mention number 155 when filling out card

Pressure Pick-ups for Aircraft and Missiles

New "Teledyne Pressure Transmitters" convert gage pressures to d-c. bridge unbalance signals strong enough for direct operation of recording galvanometers. Elastic member is a flexing ring (similar to a testing-machine "proving ring") acted upon by a frictionless piston-and-diaphragm arrangement. Four 300-ohm strain-gage elements in a Wheatstone bridge circuit are bonded to ring: two on inner surface (compression) and two on outer surface (tension). Units are approx. 3"

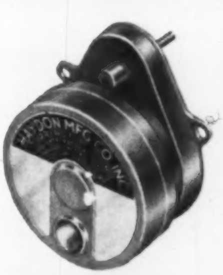
723

THERE'S A HAYDON MOTOR FOR EVERY TIMING NEED

There's a Haydon timing motor to meet your most exacting requirements — either standard in the Haydon line or engineered to your specifications.

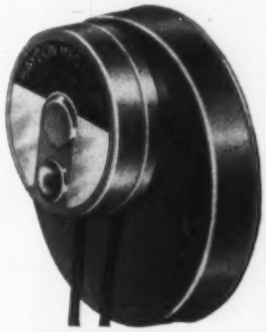
SERIES 1600

A compact, versatile motor for general use. 19 standard speeds from 1 revolution per 4 hours to 60 revolutions per minute. Available from 1/10 to 15 rpm with magnetic internal shift for reset timing applications. Also available with 1- or 2-way frictions for manual setting and magnetic brake for quick stop.



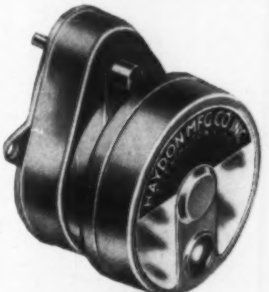
SERIES 3100

Slow speed with heavy duty gear train rated 15 pound-inches. Standard speeds: 1, 12 and 24 hours and 7 and 14 days per revolution. Many special speeds available. Frictions for manual setting, anti-backlash and brake features for extreme accuracy are optional.



SERIES 4400

A new, slow-speed motor specifically designed for applications requiring dependability and low cost. Gear train rated 20 ounce-inches. Standard speeds: 12 and 24 hours and 7 days per revolution. Other speeds from 1 1/2 to 1,000 hours per revolution available in 4100 Series.



ALL HAYDON TIMING MOTORS FEATURE: Small size • Mounting in any position • Slow rotor speed (450 rpm) • Sealed reservoir for motor lubrication • Completely enclosed construction • Capillary lubrication of gear train

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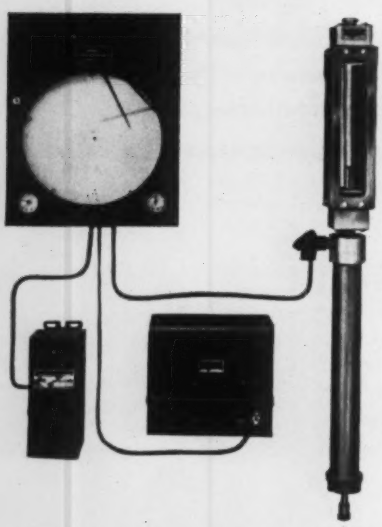
HARNESS TIME TO YOUR PRODUCTS

SUBSIDIARY OF GENERAL TIME INSTRUMENTS CORPORATION

The INDUCTRONIC remote recording-controlling Rotameter



The Inductronic remote-reading rotameter is based on the electrical induction bridge principle, but with one very significant difference—the unbalance in the bridge circuit is amplified electronically. With the power thus obtained, the recording and controlling movements are operated with servo motor drive, which gives great speed and accuracy. Also, a built-in automatic voltage regulator prevents line surges from affecting the operation or accuracy of the instrument. The "Inductronic" is obtainable as a remote recorder or recorder-totalizer or recorder-controller. For full details, write for Bulletin No. 2.

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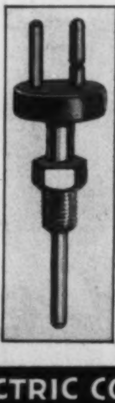

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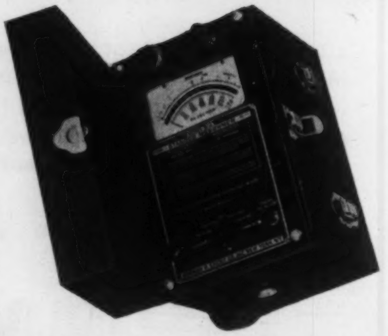
FAIR LAWN, N.J.

A REALLY USEFUL SERVICE INSTRUMENT!

4 METERS IN 1

NEW MODEL B-6

MEGOHMER



❶ **Insulation Tester,** 0-200 megohms, 500 volts DC test potential. With exclusive triple-color grading scale.

❷ **Ohmmeter,** 0-2000 ohms.

❸ **AC Voltmeter,** 0-150/600 volts.

❹ **DC Voltmeter,** 0-150/300 volts.

Full details in Bulletin 441

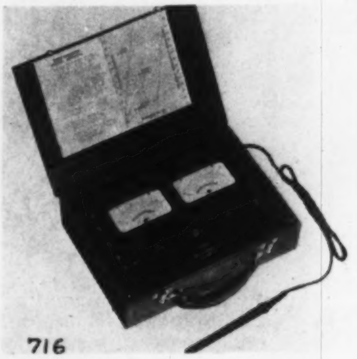
HERMAN H. STICHT CO., INC.
27 PARK PLACE NEW YORK 7, N. Y.

diam. by 3¾" long; weight approx. lbs. Seven units are announced: 0-100 lbs./in.^{2} to 0-5000 lbs./in.^{2}. Temperature coefficient less than 0.04% per deg F.; operating temperature range −5°F to 170°F. Applications: aircraft and missiles.—*Frederick Flader, Inc., 5 Division St., North Tonawanda N. Y.*

Please mention number 156 when filling out card

Fluxmeter

New "Model 327" Smith magnetic fluxmeter measures a-c., d-c. and transit magnetic flux densities. It uses small probe for measuring fields approaching point area and also thin enough to be readily inserted in air gap of average

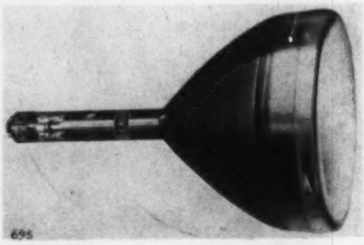


electrical machine. Probes can be supplied in special thicknesses. To operate, select desired range, set zero on gaussometer and balance milliammeter, place probe tips in magnetic field and read gaussometer at maximum, apply gaussometer reading to curve of corresponding range current, find flux reading at left of curve in kilogauss. Probe contains copper-constantan thermocouple. Standard range 0 to 26,000 gauss. Special ranges available. Calibrated accuracy, 1 percent. Connections provided for oscillographic studies of flux.—*Associated Research, Inc., 231 S. Green St., Chicago, Ill.*

Please mention number 157 when filling out card

Oscillograph Tube

New "RCA-10KP7" oscillograph tube for radar indicator service is 10-inch directly-viewed cathode-ray tube of magnetic-deflection and magnetic-focus type. Also useful in general oscillographic applications where temporary



record of electrical phenomena is desired. Long-persistence, cascade (two-layer) screen exhibits greenish-yellow phosphorescence which persists for several minutes under conditions of adequate excitation and low ambient light. Electron gun provides high effective resolution even when tube is operated with high beam current. Face plate is almost flat.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*

Please mention number 158 when filling out card

Ion Chamber Charger-reader

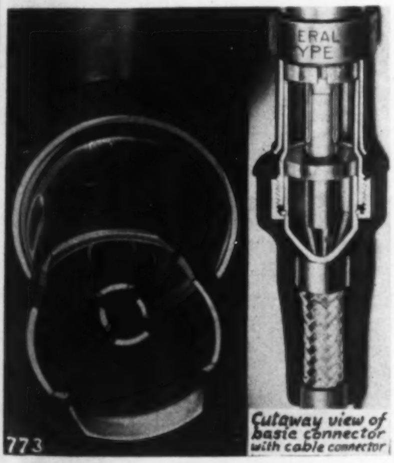
New "Model 2050" charger-reader, for use in conjunction with pocket type ionization chambers, will charge chamber to known voltage, and will measure residual chamber charge after exposure to radiation. This 110-volt a-c. operated voltmeter and electrometer will charge and read maker's "Model 3340" diaphragm-type pocket meter, and by rotation of selector switch, non-diaphragm type pocket ion chamber can also be checked. All "charge" and "read" observations are made on a 3-inch instrument with linear scales. Accuracy is 2.5 percent of full scale. Regulating circuits allow stable operation with power variation from 95 to 130 volts. Steel cabinet, 6 × 5 × 10.5 in., has provision for storing up to seven pocket ion chambers.—*Nuclear Instrument and Chemical Corp., 223 W. Erie St., Chicago 10, Ill.*

729

Please mention number 159 when filling out card

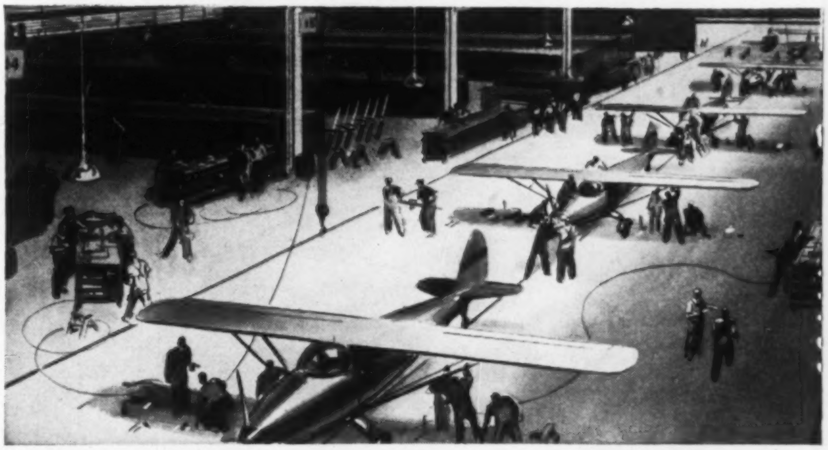
Coaxial Connector

New "Type 874" coaxial connector is a universal unit: two identical connectors plug smoothly into each other without any intermediate elements, avoiding complication of male and female ends. Connector has excellent electrical characteristics for use in 50-ohm coaxial lines at frequencies from zero to above



773

Seven new planes completed ...at a cost of $4.30!



New planes can't fly without control cable, and this manufacturer needed some—fast. He got it the same way he regularly gets many supplies and parts—by Air Express. Ordered in A.M., delivered to plant same day. 500 miles, 28 lbs., Air Express charge only $4.30. So production continued without a break.

NATION-WI
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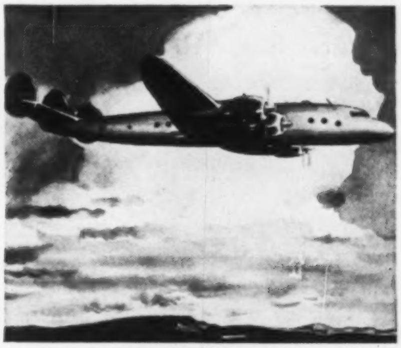
$4.30 included pick-up and delivery at no extra charge—and receipt for shipment. All this, plus the *world's fastest shipping service.* That's Air Express—used with profit by every business.



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Same day delivery in both cases if you *ship early.*

Only Air Express gives you all these advantages: Special pick-up and delivery *at no extra cost. You get a receipt for every shipment* and delivery is proved by signature of consignee. One-carrier responsibility. Assured protection, too—valuation coverage up to $50 without extra charge. Practically no limitation on size or weight. For fast shipping action, phone Air Express Division, Railway Express Agency. And specify "Air Express delivery" on orders.

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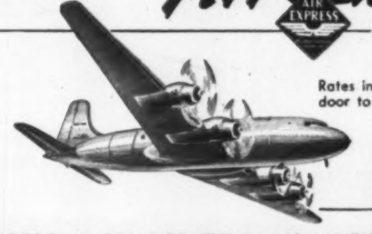

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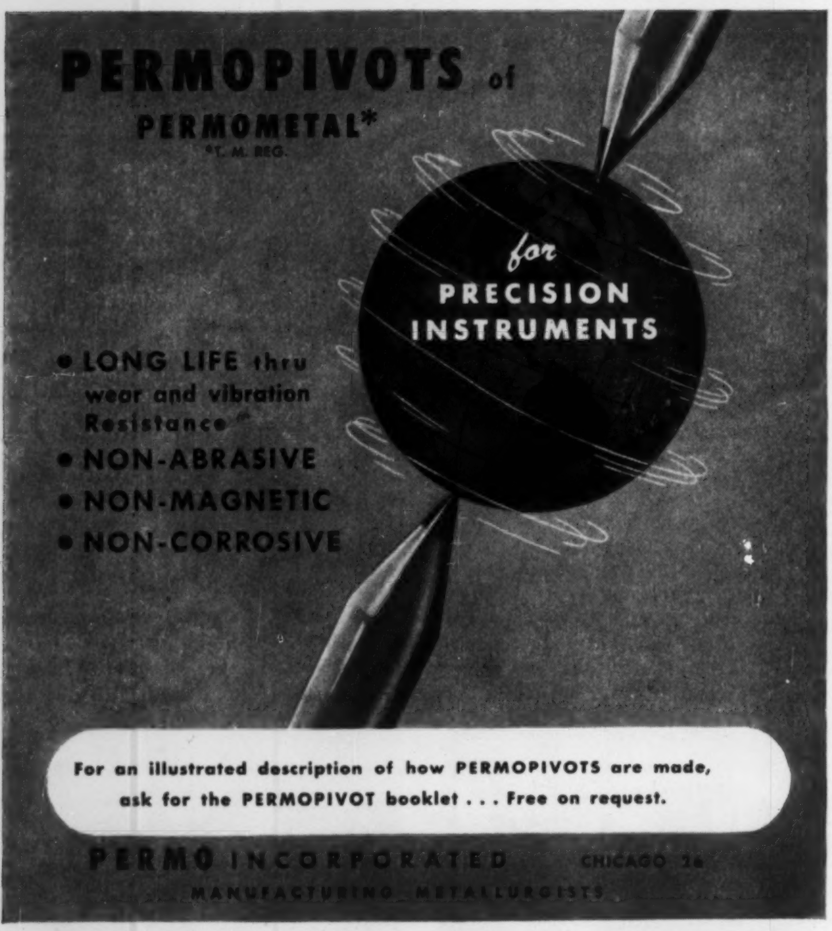

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PERMOMETAL*
*T. M. REG.

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PRECISION INSTRUMENTS

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MANUFACTURING METALLURGISTS

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For INSTRUMENTS

IT is a recognized fact the world over that porpoise jaw oil is the finest crude from which to refine lubricating oil for delicate instruments of precision. When the refining is done by the scientific processes developed through years of experience by Wm. F. Nye, Inc., the result is a specialized oil of the very highest quality.

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4500 Mc. Characteristic impedance is 50 ohms throughout connector; reflections are minimized; standing wave ratio is less than 0.3 db at all frequencies below 4500 Mc. Flexible polyethylene cable (50 ohms) is also available for use with new connectors.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Please mention number 160 when filling out card

Smoke Density Meter

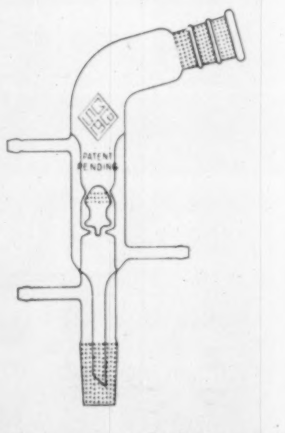
New model of instrument for smoke density measurements of oil-burning equipment and for sampling dust in at-

mosphere makes permanent record of actual smoke sample on paper test disk. (Original model described in April 1947 issue, page 302.) It is motor-driven, has time control switch and can be adjusted to practically any desired smoke density range by varying sampling interval between 30 and 90 seconds.—*Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.*

Please mention number 161 when filling out card

Vacuum Adapter for Fractional Distillation

New "Theimer" glass vacuum adapter for fractional vacuum distillation contains no stopcocks, but employs internal glass valve which is automatically lubricated by distilling liquid. All manipulation is in three-way stopcock in

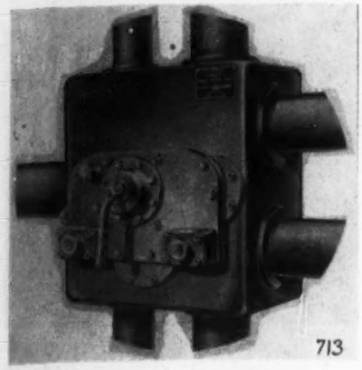


pump system, removed from contact with distillate. This stopcock does not require cleaning after each distillation. Two models of new adapter are available in variety of sizes of standard taper or semi-ball connections. One model, with jacket around valve, is used for circulation of coolant when distilling extremely limpid materials or of warm liquid with viscous materials. Other model, without jacket, is satisfactory for normal distillates.—*Scientific Glass Apparatus Co., Inc., Bloomfield, N. J.*

Please mention number 162 when filling out card

Zeolite Control Valve

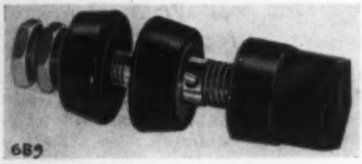
New single control valve for zeolite softeners has built-in backwash and rinse rate controllers. Valve is six-position type with two standby positions. Operating positions provide separate control of backwash, regenerant feed, rinse and service. Available for control of all types of ion exchange systems and pressure filters.—*Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia 32, Penna.*


713

Please mention number 163 when filling out card

Five-way Binding Post

New 5-way binding post is adaptable for permanent clamping, spade lug connection, plug-in for banana plugs, looping and clamping, and clip lead. Posts are rated 30-ampere capacity and 1,000-volt working voltage.—*Superior Electric Co., 430 Hannon Ave., Bristol, Conn.*

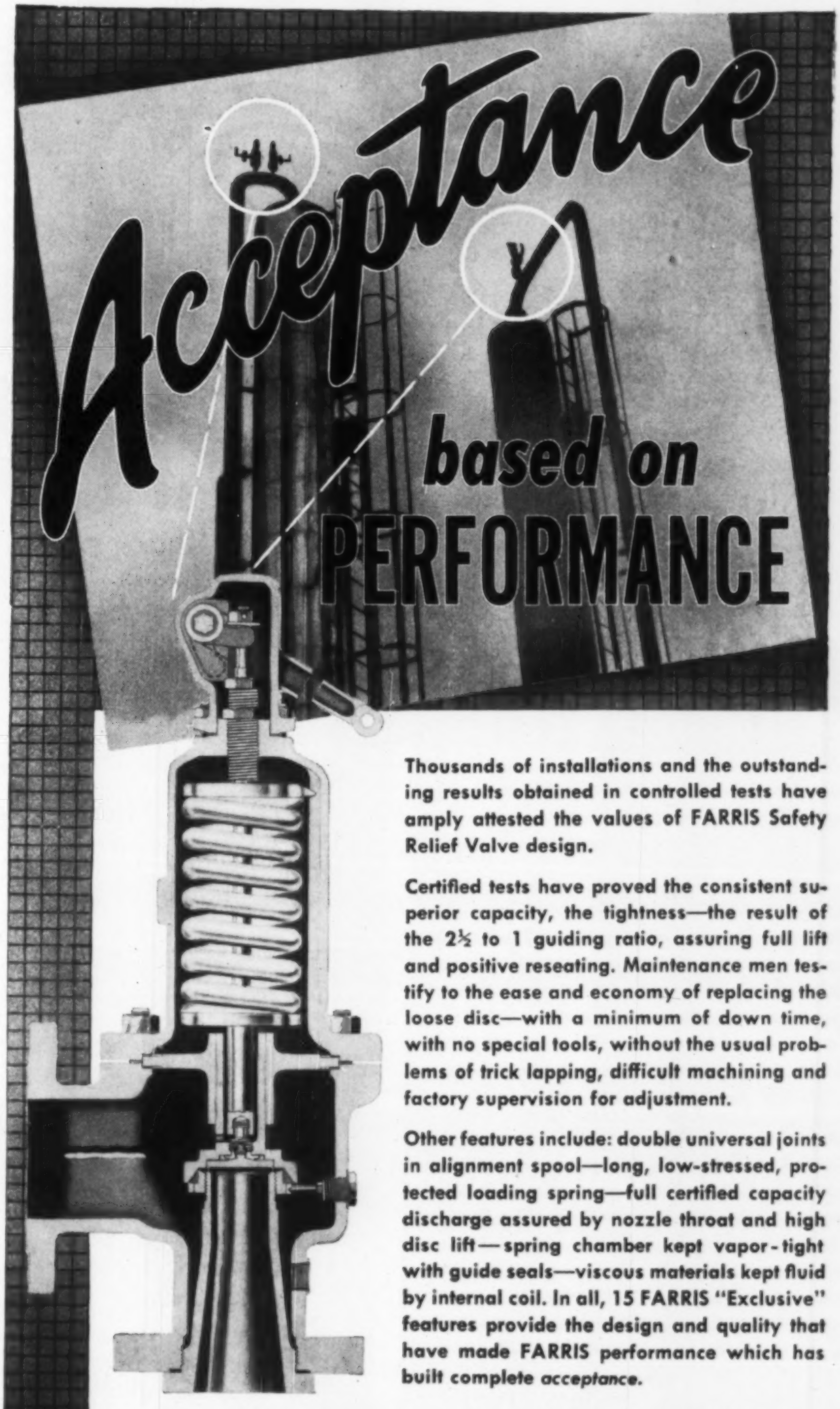

689

Please mention number 164 when filling out card

Wide-range Oscillator

New model "Megamarker" oscillator incorporates wider range of frequency (29 to 39 Mc.) than maker's standard

745



Thousands of installations and the outstanding results obtained in controlled tests have amply attested the values of FARRIS Safety Relief Valve design.

Certified tests have proved the consistent superior capacity, the tightness—the result of the 2½ to 1 guiding ratio, assuring full lift and positive reseating. Maintenance men testify to the ease and economy of replacing the loose disc—with a minimum of down time, with no special tools, without the usual problems of trick lapping, difficult machining and factory supervision for adjustment.

Other features include: double universal joints in alignment spool—long, low-stressed, protected loading spring—full certified capacity discharge assured by nozzle throat and high disc lift—spring chamber kept vapor-tight with guide seals—viscous materials kept fluid by internal coil. In all, 15 FARRIS "Exclusive" features provide the design and quality that have made FARRIS performance which has built complete *acceptance*.

NEW 72-PAGE CATALOG JUST RELEASED

32 pages of Data. See the FarriSeal Bellows Corrosion-resistant Valves. FARRIS Pinch Valve.

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Farris

1722

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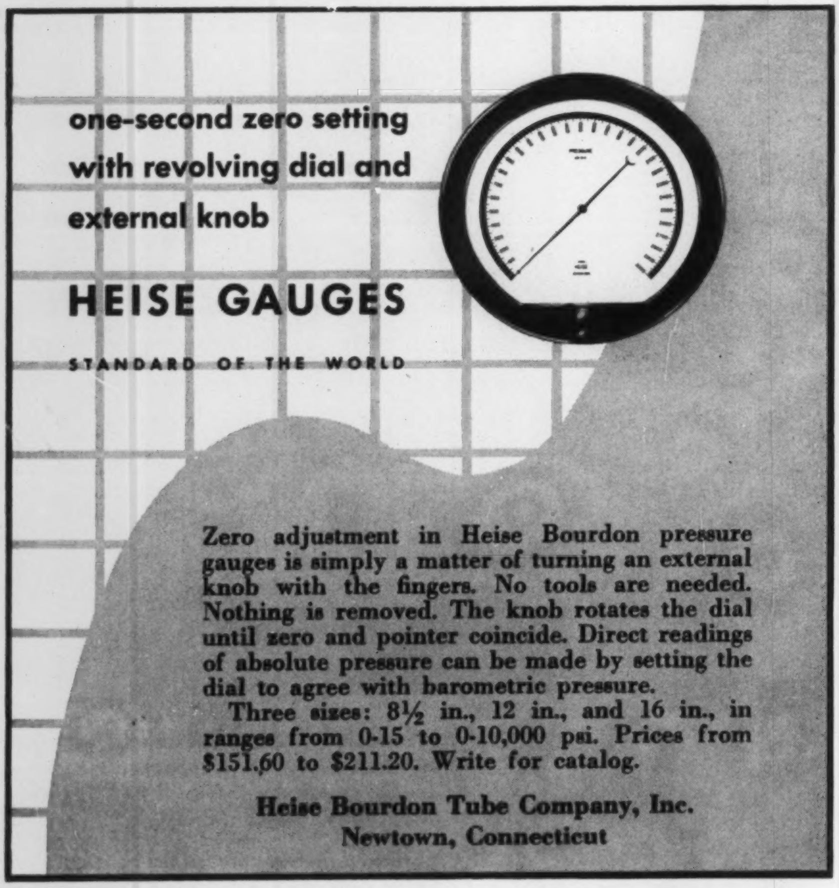


one-second zero setting with revolving dial and external knob

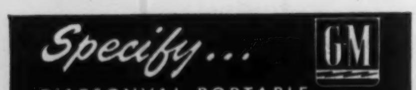
HEISE GAUGES

STANDARD OF THE WORLD

Zero adjustment in Heise Bourdon pressure gauges is simply a matter of turning an external knob with the fingers. No tools are needed. Nothing is removed. The knob rotates the dial until zero and pointer coincide. Direct readings of absolute pressure can be made by setting the dial to agree with barometric pressure.

Three sizes: 8½ in., 12 in., and 16 in., in ranges from 0-15 to 0-10,000 psi. Prices from $151.60 to $211.20. Write for catalog.

Heise Bourdon Tube Company, Inc.
Newtown, Connecticut



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D'ARSONVAL PORTABLE

GALVANOMETERS

AND MOVEMENTS...

New!

Series 570-600
Pointer-Type
D-C Galvanometer

Here is a new addition to the line of G-M galvanometers. It is a completely assembled unit featuring an Alnico magnet for greater stability of calibration and a new high in sensitivity. Easily installed and replaced, requires only 2¾" below the mounting surface. Rugged construction throughout. Three models, with sensitivities per mm. division of .06, 0.10 and 0.20 microamps.

Write for specifications and prices on these and other galvanometers

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LENSES, PRISMS or related
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Natural or Synthetic
CRYSTAL OPTICS
Lithium fluoride, sodium
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Fused or natural quartz
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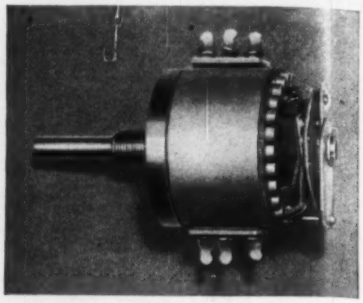
model (19 to 29 Mc.). All models have accuracy of 0.25 percent and crystal oscillator for calibrating variable oscillator; they also provide marker at 4.5 Mc. for adjusting television sound discriminator. — *Kay Electric Co., Pine Brook, N. J.*

Please mention number 165 when filling out card

V. U. Instrument Multiplier

New V.U. instrument multiplier provides five-step straight T performance in size normally limited to ladder and voltage-divider circuits. Extra terminals increase utility of unit, since in "off" position, V.U. multiplier network is automatically disconnected from line which it normally bridges, and V.U. instrument, completely isolating both. Instrument is connected to auxiliary pair of terminals on multiplier when in "off" position, thus enabling instrument to be used for volume indication on another line, for tube checking and other purposes. Modifications of standard units can be produced.—*Shallcross Mfg. Co., Collingdale, Pa.*



Please mention number 166 when filling out card

D-c. Voltage Multiplier for VTVM

New d-c. voltage multiplier for maker's "Polymeter" extends measurements to 10,000 volts; consists of a 48-in. plug-in flexible lead tested for 22,000-volt breakdown; Nickel-plated brass contact pin mounted in tapered polystyrene rod 1.75 in. long; a removable Bakelite safety flange; and varnished Bakelite handle enclosing dropping resistor tested at 30,000 volts. — *Tube Div. of Sylvania Electric Products, Inc., 500 Fifth Avenue, New York 18, N. Y.*

Please mention number 167 when filling out card

Automatic Timer

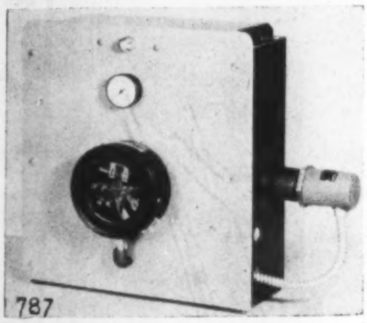
New "Type DB" timer for automatic timing of continuous processing work where process periods bear a percentage

relationship to total time cycle is said to eliminate need for multiplicity of timers arranged in cascade system. Entire process combining many operations can readily be set up on single dial. Total time cycle and individual periods are adjustable. Speed range is in ratio of 36 to 1.—*Struthers-Dunn, Inc.*, 150 *N. 13th St., Philadelphia* 7, *Pa.*

Please mention number 168 when filling out card

Automatic Controller for Steam Return Line Treatment

New "Pressure-Jet System" of corrective treatment comprises two factors: "Pressure-Jet Unit" and "Pres-

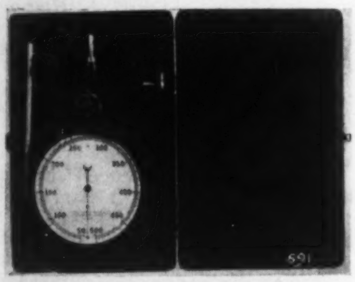


sure-Jet Fluid." Unit is easily installed and completely automatic. Operates either on 110 or 220 volt a.c. or d.c.—*Pressure-Jet Systems, Inc.*, 528 *Citizens Bldg., Cleveland* 14, *Ohio.*

Please mention number 169 when filling out card

Hand Tachometer

New "Model 4800" tachometer is of mechanical centrifugal type, indicating in either direction of rotation. Three



ranges furnish speed indication from 50-50,000 rpm. or 25-25,000 rpm. Range selection is accomplished by rotating

MEASUREMENTS CORPORATION *MODEL 80*

STANDARD SIGNAL GENERATOR

2 to 400 MEGACYCLES

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE 0.1 to 100,000 microvolts

OUTPUT IMPEDANCE 50 ohms

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
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Television and FM Test Equipment

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TEST YOUR MAGNETIC CIRCUITS

RAWSON FLUXMETER TYPE 504

The only portable fluxmeter available which returns rapidly to zero when a single button is depressed. Simple and fast in operation. Convenient and light in weight.

Not limited to a single type of measurement. Has universal application for laboratories or production. Measures strength of magnets and electromagnets, permeability and hysteresis loops for iron and steel, total flux lines in circuit, flux lines developed in air gap, etc.

Has a mechanical clamp to protect the pivots and jewels when in transit.

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TELEMETERING GYROS

Giannini telemetering units include rate gyros calibrated for rotational measurements of 10° to 1000° per second, and position gyros with one or two axis electrical sensory elements. All gyros operate from 24 volts dc.

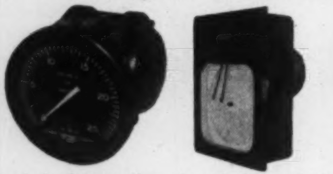
Recently expanded manufacturing facilities afford firm delivery of 1949 improved instrument and powerplant equipment.

Latest Technical Catalogs on Request

GM *Giannini* & CO INC
285 W. Colorado, Pasadena 1, California
697 Morris Turnpike, Springfield, N. J.

TWO SMASH HITS!
The NEW Barton Indicating and Recording Flow Meters

MODEL 200
DIFFERENTIAL
PRESSURE
INDICATOR



MODEL 202
DIFFERENTIAL
PRESSURE
RECORDER

For the first time, a long desired operating characteristic of the actuating element in flow meters has been achieved by Barton Instrument Company.

Stainless Steel Rupture-Proof Bellows • Torque Tube Drive • Self Venting or Draining Actuating Unit • Removable Pressure Chambers • Differential Range: 0-20 W.C. to 0-300 W.C.

Write for Preliminary Data Sheets 200-1 and 202-1

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3502 UNION PACIFIC AVE., LOS ANGLES 23, CALIF.

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 41 years.

In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

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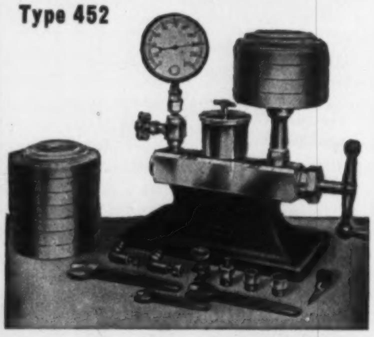
AMTHOR Dead Weight Pressure Gauge TESTER
Type 452



Modern design and construction puts this rugged precision instrument in a grade above the ordinary deadweight testers.

Made in ten ranges, to 5000 lbs. maximum.

We guarantee 1/10 of 1 percent accuracy in each range.

The Type 452 is designed for simplicity and compactness. It incorporates the newest refinements and improvements. Adapters and tools are supplied, as well as either carrying case or protecting cover.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems.

Drop us a line today.

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Surfaced or drawn flat glass, cut, edged and drilled to your specifications.

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knob marked “Low, Medium, High.” Pointer holds measured speeds after instrument has been disengaged, until disengaged by push button.—*Jones Motrola Corp., 463 Fairfield Ave., Stamford, Conn.*

Please mention number 170 when filling out card

Liquid-level Controller

New “Acrafloat” automatic liquid level control switch is of magnetic type, operated by a free float encased in a vertical metal pipe; is claimed to control and indicate liquid levels “to a fraction of an inch within required vertical differentials of many feet.” It consists of a float unit (Fig. 1) and a control unit (Fig. 2), latter designed for operating pump motors, valves or indicating lights.—Dept. A, *Clapp Instrument Co., Webster, Mass.*

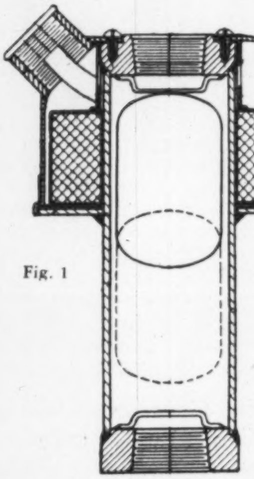

Fig. 1

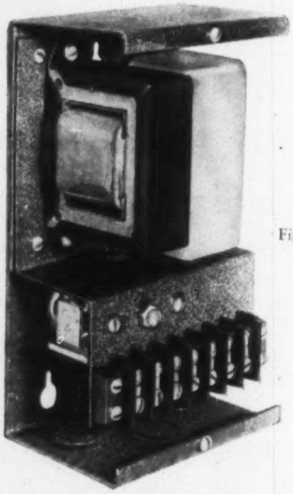

Fig. 2

Please mention number 171 when filling out card

Automatic Piston Inspector-classifier

New model of “Multicheck” performs simultaneous check of eleven critical dimensions and determinations of one of five skirt diameter classifications of diesel pistons. Master light shows whether all dimensions are within specified tolerance limits by changing from red to white. Individual signal lights show whether dimensions are under or

over tolerance limits. "Electrigage Head" permits easy and quick classification according to the skirt diameter. —*The Sheffield Corp., Dayton 1, Ohio.*

Please mention number 172 when filling out card

Indicating Electrical Instruments

New panel instruments for d.c. and a.c. measurements are matched for mounting on same panel; are of three types: permanent-magnet, iron-vane, and solenoid types. Also announced are large needle-tipped instruments with hairspring repulsion type movement fitting some cases, with 5% accuracy guaranteed.—*Sterling Mfg. Co., 9205 Detroit Ave., Cleveland, Ohio.*

DIRECT CURRENT
0
20
40
60
80
100
MILLIAMPERES

Please mention number 173 when filling out card

Multi-range Kilovoltmeters

CORRECTION.—Dec. issue, page 1116, in description of new instrument made by Beta Electronics Co., sixth line from bottom of page, "20 ma. full-scale" should read "20 microamperes full-scale."

Elementary Engineering Electronics

With Special Reference to Measurement and Control

By ANDREW W. KRAMER

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NEW!
FM SIGNAL GENERATOR
MODEL 202-B

FREQUENCY RANGE
54 to 216 MEGACYCLES

The model 202-B is specifically designed to meet the needs of television and FM engineers working in the frequency range from 54-216 mc. Following are some of the outstanding features of this instrument:

RF RANGES—54-108, 108-216 mc. ± 0.5% accuracy.

VERNIER DIAL—24:1 gear ratio with main frequency dial.

FREQUENCY DEVIATION RANGES—0-80 kc; 0-240 kc.

AMPLITUDE MODULATION—Continuously variable 0-50%; calibrated at 30% and 50% points.

MODULATING OSCILLATOR—Eight internal modulating frequencies from 50 cycles to 15 kc., available for FM or AM.

RF OUTPUT VOLTAGE—0.2 volt to 0.1 microvolt. Output impedance 26.5 ohms.

FM DISTORTION—Less than 2% at 75 kc deviation.

SPURIOUS RF OUTPUT—All spurious RF voltages 30 db or more below fundamental.

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BOONTON RADIO *Corporation*
BOONTON · N · J · U · S · A ·

DESIGNERS AND MANUFACTURERS OF
THE Q METER · QX CHECKER
FREQUENCY MODULATED SIGNAL GENERATOR
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VINELAND, NEW JERSEY

INSTRUMENTS ON THE MARCH

High-sensitivity Differential Pressure Gage

WASHINGTON, D. C.—A differential manometer that will detect pressure differences as small as one millionth of an atmosphere over a range of total pressure from 1 mm. of mercury to 1 atmosphere has been developed by Harry Matheson and Murray Eden of the National Bureau of Standards. This instrument, which operates on the principle of the aneroid barometer, can be used to compare pressures of gases, organic vapors, and noncorrosive liquids. It is particularly useful in vapor-pressure work since less than a drop of liquid is sufficient to compare an unknown vapor pressure as a function of temperature with that of a known liquid. The rest point of the new manometer is insensitive to temperature, and accidental pressure differences as high as one atmosphere introduce only temporary hysteresis effects. The instrument is also readily portable and need not be leveled before operation.

A number of sensitive differential manometers have been available. However, the majority of such gages do not operate satisfactory in the presence of vapors. Other common disadvantages are large dead volume, inconvenience of handling or moving, difficulty or slowness of manipulation, lack of precision, and sensitivity to temperature. In connection with a study, at the NBS, of high-polymer plastics in solution, it became necessar yto compare solution vapor pressures accurately. Lack of suitable apparatus for this purpose resulted in the design of the new type of differential manometer, which is expected to prove useful in other fields of research. It may also be advantageously substituted for inclined-tube gages and other commercial devices for the measurement of small differences of pressure.

The instrument developed at the Bureau measures a pressure difference as the change in the separation of a pair of nesting diaphragms indicated by an unbonded wire-resistance displacement gage. The two diaphragms are soldered together at their edges to form a very thin capsule into which is admitted one of the vapors whose pressure is to be compared. The other vapor surrounds the capsule externally.

One of the diaphragms is attached to a stationary support through which vapor enters the capsule; the other is connected to the displacement gage. The four resistance wires of the gage are arranged to form a Wheatstone bridge, in which an increased separation of the diaphragms elongates one pair of wires and shortens the other pair. A decrease in the diaphragm spacing has the opposite effect. The resistive unbalance as indicated by a galvanometer gives an accurate measure of the separation of the diaphragms, and thus of the pressure difference. The capsule and gage are sealed in a vacuum-tight chamber.

Tests of the new manometer at the NBS have shown that its sensitivity is not appreciably altered when the active elements are used at temperatures between 20°C. and 50°C., for values of absolute pressure between 1 mm. of mercury and 1 atmosphere. The elements can withstand a differential pressure of one atmosphere where the greater pressure is external to the capsule, or a pressure difference of 0.2 atmosphere in the other direction. The equality of two pressures may be found to 0.001 mm. of mercury; the direction and magnitude of a pressure inequality may be determined between 0 and ±0.5 mm. of mercury. The indicated rest point remains constant within 0.005 mm. of mercury for periods of at least one day, even though the device may be subjected during this time to pressure differentials of the order of 0.2 atmosphere and temperature variations of several degrees.

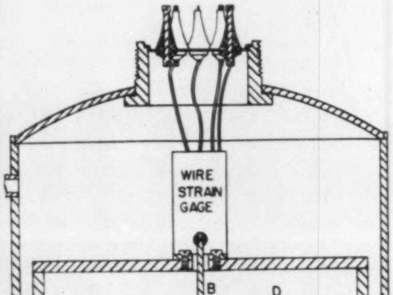
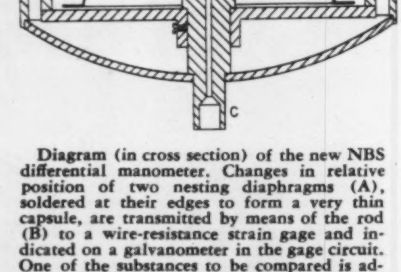


Diagram (in cross section) of the new NBS differential manometer. Changes in relative position of two nesting diaphragms (A), soldered at their edges to form a very thin capsule, are transmitted by means of the rod (B) to a wire-resistance strain gage and indicated on a galvanometer in the gage circuit. One of the substances to be compared is admitted to the interior of the capsule through the stationary support (C); the other surrounds the capsule in the vacuum-tight compartment (D).



View of ultrasensitive pressure element partly disassembled.

Neutron Counter

PITTSBURGH, Pa.—A tiny atom-smashing device, no larger than a flower pot, has been developed by the Westinghouse Electric Corp. to detect and count neutrons, the vital building-blocks in the nuclei of atoms. The neutron counter was developed jointly by Dr. William E. Shoupp, manager of nuclear physics and electronics at the Westinghouse Research Laboratories and Dr. Kuan-Han Sun, Chinese-born research physicist.

Neutrons defy all ordinary methods of detection and study since they carry no electrical charge and cannot be detected directly by electrical means. The Westinghouse scientists took advantage of the atom-splitting qualities of the neutron to devise a method for trapping them. In the neutron counter, a small amount of uranium 235 is mixed with a special light-producing phosphor. The mixture is coated on the surface of an electron-multiplier photo tube. The whole device is contained within a metal cylinder which itself is lined with a 2" thick wall of parafin to slow down fast-moving neutrons. When a neutron passes through the paraffin shield and strikes the uranium-phosphor film on the tube, it splits the uranium atom or atoms. In the tiny explosion which takes place, nuclear fragments are hurled off and strike the phosphors, producing light rays. These light rays in turn produce electrons which then are multiplied a millionfold and collected at the end of the tube.

Thus neutrons recorded as flashing peaks of light on a fluorescent screen can be observed directly or the electrical impulses can be transmitted to electric circuits to give an accurate count of the atomic explosions taking place. The new detector can count the particles cast off by the exploding atoms at the rate of 100,000 a second—fifty times faster than the standard Geiger counter.

The detection of mesons—components of cosmic rays—may also be possible with the new instrument. "Although our work thus far has been confined to the recording of neutrons," Dr. Kuan said, "there apparently is no reason why the same instrument cannot be used to detect the heavy mesons recently discovered existing in the upper atmosphere and artificially made in the modern giant cyclotron."

The neutron counter is based on the working principle of another atomic ray detector, a scintillation counter, developed last year by Dr. Fitz-Hugh Marshall and Dr. John W. Coltman of the Westinghouse Research Laboratories (*Instruments*, Sept. 1947, page 782).

Smell-control of Natural Gas

SCHENECTADY, N. Y.—A General x-ray photometer, originally designed to measure the tetraethyl lead content of gasoline, now is being used by the Standard Oil Company of California to control the amount of unpleasant odor introduced into natural gas. The odor in the gas is a protection for housewives and industrial workers, making it possible for them to notice any leak in a natural gas line before it becomes dangerous. By using an x-ray photometer, devised several years ago by the G-E General Engineering and Consulting Laboratory, the amount of smell emitted by the gas is being controlled.

The smell comes from sulphur compounds chemically known as mercaptans. According to Standard Oil engineers, a small quantity of correctly balanced mercaptan in a room is sufficient for quick identification. Mercaptans with too little sulphur, however, are unnoticeable, while those with excessive sulphur are intolerable, they said. The engineers pointed out that the x-ray photometer finds a valuable application in controlling this sulphur content of mercaptans.

The instrument operates by measuring the extent to which a test material absorbs a beam of x-rays. By comparison with materials for which the absorption rate is known, the instrument determines the quantity of any material mixed with another material of different atomic weight.

In operation, the photometer directs an x-ray beam at a flourescent screen. The intensity of the beam, after it has passed through the material under test and is transposed into visible light by the fluorescent screen, is measured by photoelectric equipment; the final reading is given on a dial.

X-ray Movies Use Radar Idea

BLOOMFIELD, N. J.—A technique borrowed from wartime radar sets has provided the peak power flashes needed to make super-speed x-ray motion pictures. Donald C. Dickson of the Westinghouse Research Laboratories in Bloomfield, N. J., stated at the National Electronics Conference that a special high-voltage radar-type pulse transformer and an electronic tube are key units in making exposures of 10 millionths of a second on x-ray film moving at 150 frames a second. The tremendous surges of high-voltage power necessary to make these exposures are similar to the split-second pulses required to transmit radar signals.

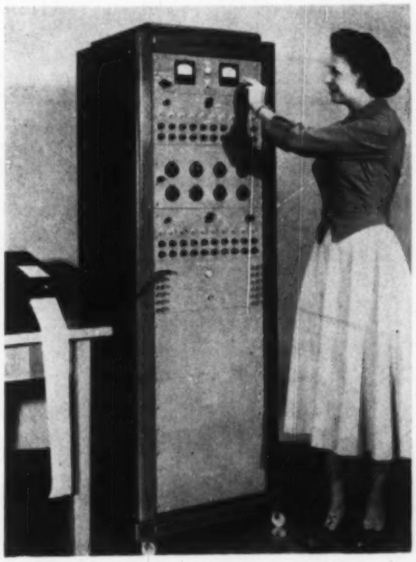
Exposures of 10 microseconds or faster are needed to hold motion blurring to a minimum when capturing on swiftly moving x-ray film the phenomena that occur when live rockets are fired. Mr. Dickson explained that the research leading to the development of high-speed x-ray movies was conducted by Westinghouse for the eventual purpose of analyzing the burning action of fuel in a rocket. The project was sponsored by the Navy's Bureau of Ordnance.

Modifications of this super-speed x-ray equipment could be made to suit medical or industrial uses. As an example, physicians could capture on movie film visible evidence of the fastest moving organs within human bodies; in industry, the mysteries of how metal is deposited from an arc welding rod and how molten metal flows into a casting mold might be solved.

Automatic Computer for Aircraft-motion Mathematics

AKRON, Ohio—An electronic "slide rule" that solves problems of motion just as fast as it takes for the motion to happen and gives the answers in a steady stream on a special tape has been designed and built by the Goodyear Aircraft Corp. here.

Developed under special contract with the United States Air Force, the computer operates on power supplied from any wall socket. It is two feet square, six feet tall, weighs approximately 800



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GUEST EDITORIAL

Concluded from page 32

be if the pilots could always be present to tell their side of the story, it nevertheless points out the direction our greatest efforts must take if we are to achieve any major reduction in aircraft accidents. In most cases it is quite unfair to speak of 'pilot errors' when in actuality they are 'designers errors' which have made the pilot's task excessively difficult. Our greatest oportunities for increasing the safety of aircraft are in the improvement of the design of the pilot's tools, namely, the levers, knobs and switches by which he controls his craft, and the multiplicity of instruments from which he obtains his information."

Considerable research is under way at the Aero Medical Laboratory of the USAF Air Materiel Command on ways of designing instruments to improve their readability.

The reliability of instruments has been made a study in design by many who have taken the broader viewpoint of making their product most helpful to the user. It should be acknowledged as a very important feature of instruments design for all purposes.

6. In addition to improving process capacity and efficiency, and saving of labor, there should be added full consideration of the use of instruments for safety of operation of process equipment.

There is another phase of safety—that is, detection of conditions at the time of an accident or mal-operation of equipment. Very often a comparison of records taken through a cycle proves without question just what took place, thereby enabling corrective measures to be taken in the design of equipment or in its method of operation.

7. There is a great deal for engineers to do in the intelligent application of instruments to industry. We should avoid over-zealous extension or promotion of the industry. Personally, I think it is time to stop, look, and listen, that this industry does not lose its balance and overdo the promotional and extensive duplication of ideas that create into many industries. Sooner or later come days of reckoning, when the survival of the fittest and the weeding out of unnecessary elements take place.

To best meet the demands of the future we should fully meet the problems of today. Certain important needs of the future will be the continuation of trends of today, thereby requiring similar types of instruments and controls.

We will certainly have problems of measuring temperatures considerably higher than those of today. Not only will the tempartures of steam, and other process fluids be carried higher than those now in use, but temperatures from the combustion of fuels will undoubtedly be above those now considered usable by several hundred degrees. There will be a real problem to measure these temperatures with the products of combustion and impurities carried therein.

In addition to continued use for measuring the flow of gases and liquids, we will probably need to measure the flow of mixture of both, and also an admixture of solids in suspension.

There will be a greater need for instrumentation applied to the chemical and physical analysis of materials in streams of flow, and from such measurements, control of composition. We will probably be called upon to measure and communicate properties or functions of materials and forms of energy beyond any now within our realm of knowledge, or even speculation.

This industry is in a very strategic and enviable position. It is useful and essential. It has very wide application in many of the industries and processes known today and will hold an increasingly important position in more complicated processes yet to come.

---

pounds and contains 100 radio tubes. It solves linear differential equations in one-tenth the time required by an engineer. Once set for a particular equation, it will give answers in the same length of time required for the actual operation to take place.

In effect, the operator writes his equation with electrical circuits. A board similar to a telephone switchboard with a number of plug sockets is used to simulate different equations by a variety of circuit combinations. Known contants in the equation are set into the machine by varying the value of the electrical resistance connected to the twenty amplifying units.

Air Force requested the machine be built to assist researchers working on problems of motion in aircraft. Actual flight of the airplane is duplicated by the electrical current in the machine. Answers are obtained by translating the electrical impulses into the motion of a recording pen.

One unit is designed to perform twenty separate mathematical operations, but two or more units may be wired together for more complicated problems. Should the answer to any given problem, through an error in setting up the equation, become too large for the computer, warning lights on the control panel will flash. Two of the computers wired together will solve approximately 90 percent of all computations that face aircraft researchers.

Two units have been turned over to the Air Force and others will be used by Goodyear Aircraft and the University of Michigan.

Instrument "Road Show"

SCHENECTADY, N. Y.—With more than 9,000 miles of cross-country travel already behind it, General Electric's rolling "Carnival of Measurements" exhibit has embarked on a year-long, 14,000-mile tour of eighty major U. S. Industrial centers.

Featuring "Instruments in Industry," the collection of more than 150 electrical measuring devices manufactured by the G-E Meter and Instrument Divisions, West Lynn, Mass., will include executives and engineers representing utilities, municipalities, industries, research laboratories and governmental agencies and representatives of schools, colleges, and engineering societies.

Since completion of the first lap of the tour which took it to 21 major cities in the northeast, mid-Atlantic, and mid-western states, the exhibit has been brought up to date. Now it consists of panels on which are displayed switchboard, panel, and aircraft instruments; instrument accessories and components; photometric devices and photovoltaic cells; time switches; portable testing instruments; remote position indicators; recording instruments; instrument transformers; laboratory instruments; watthour meters; and telemeters.

Illustrated talks on the operation and application of the instruments are given at each showing by J. M. Whittenton, sales manager of the electric instrument division, and R. W. Kunkle of the marketing service division, or other representatives of the G-E West Lynn, Mass., Works.

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Vol. 4 **January 1949** **No. 1**

General News

To the Members of the Instrument Society of America,

GREETINGS:

Again we are at the beginning of a New Year. For a young organization such as ours, it will be an important New Year as are all early formative years. Like the youngsters that all of us once were, we learn more and grow faster, proportionately, in the earlier years, than we are ever to learn or grow afterwards. (We have only to remember the words of the educator: Give me a child before he is seven, and I can tell you what kind of an adult he is going to be.)

The Instrument Society is celebrating the start of its fifth New Year. Since that meeting in New York in December 1944 when representatives of various local societies first met somewhat informally, and then later in April 1945 in Pittsburgh, when the representatives of fifteen local societies met formally and formed the Instrument Society of America, we have grown until now we have more than forty local sections within and even outside the boundaries of the United States. Under the wise leadership of Sperry, Fairchild, and Exline — our past presidents, we have earned a position of distinction and now take our place with sister organizations side-by-side, in the technical world. We can point with pride to annual conferences and exhibits held in Pittsburgh, Chicago, and this past September, to the historic ones in Philadelphia.

You, the Members, are all part of our success in achieving our present position. You are all part of our hope and promise for the future.

A Happy New Year to you All!

Carl F. Kayan
President.

EXECUTIVE COMMITTEE MEETS IN NEW YORK, DEC. 1-2

The Executive Committee held a two-day meeting in New York on Dec. 1st and 2nd with Carl Kayan, H. C. Frost, Fred Trapnell, J. B. McMahon, Lyman Allen, H. Barnum and Richard Rimbach present. A few committee chairmanships were settled as follows:

Meetings Committee, Ed. Grace
Finance Committee, George Feeley
Constitution, Earl Rieger
Publication, Ralph Batcher
Rules and Procedures, C. C. Vogt

A special committee was formed under the chairmanship of Ralph Batcher to study the frequency of exhibits.

The Secretary was empowered to employ additional non-executive personnel, salary of $200-$300 per month, to be paid out of the non-executive salary part of the budget and to obtain subsequent approval for a deficiency budget from the Board of Directors at Toronto in May 1949.

Various reports by committees and interim reports of the vice-presidents were accepted or passed on to standing committees for their use.

The next meeting of the Executive Committee is to be held in Chicago sometime in March 1949.

PITTSBURGH TRIES ANALYZING MEETING PROGRAM

At a recent meeting of the Pittsburgh Section, cards were passed out to those present for the purpose of rating the talk. The card is reproduced herewith

---

ISA Meeting ....(date)
Member ☐ Associate Member ☐ Guest ☐
What is your opinion of tonight's talk?
Do you rate it . . .
excellent ☐ fair ☐ poor ☐
How much are you interested in the subject?
Very much ☐ fairly ☐ very little ☐
Would you like the Society to arrange for another talk on the same subject in the near future? yes ☐ no ☐
How was the presentation:
excellent ☐ fair ☐ poor ☐
Critical remarks and suggestions........
....
No signature required

Results were as follows:

Out of 94 cards distributed to about 125 present, 45 replies were received:

Number of replies 45, of which 32 are members and 13 guests 71%—29%.
Percentage of replies: 48% of cards disdistributed 36% of those present.
Talk was rated excellent by 35, fair by 10. 78%—22%
Interested: very much 24 (55.3%), fair by 18 (40%), very little by 2 (4.4%). No reply 1—(203%).
Another talk on same subject requested: yes 27 (60%), no 10 (22%), no opinion 8 (18%).
Presentation rated: excellent by 31 (69%), fair by 14 (31%)

Nine cards offered critical remarks and suggestions: there were several critical remarks with regard to poor arrangement of the light switches, a suggestion that participants in the discussion should go to the microphone—otherwise the questions are not audible in the rear, suggestion that the talk should not be read off a manuscript and that the discussion should be kept on the subject. The three most constructive suggestions are: (1) that more than one speaker on a subject be provided; (2) that the next time a speaker be chosen who takes a positive stand or at least will give a full discussion of it; (3) that more pertinent data such as costs, etc. be given.

Possibly other sections would like to try this scheme. It is often difficult to determine what the members want and this method may, if used for several meetings, gradually give the program committee a better understanding of the type of talks the section's members desire.

PHILADELPHIA RUNS GADGET CONTEST

The Philadelphia Section has sponsored a "Gadget Contest" and prize winners are announced in the Section News Reports. The more one thinks about the subject of gadgets, knowing instrument men, the more it becomes apparent that such a contest holds promise of a lot of fun for the members and, by no means a slim chance that several useful devices will be developed.

Aruba thinks highly of the contest and "The Aruba Bulletin" for November 1948 says that they plan to publish some of the gadgets for the edification of Aruba Section members. The suggestion has also been made that this idea could be adopted nationally. Aruba's members are asked to give their thoughts on a national gadget contest to the section secretary. If members of other sections care to transmit their comments to the Journal Editor, I will pass them on for consideration by the Executive Committee.

REGISTRATION LIST FOR 1948 CONFERENCE

The list of those who registered at the 1948 National Instrument Conference and Exhibit has been prepared and distributed to Exhibitors by the National Office. The names are arranged under employing firms and the firm names in alphabetical order. The occupational, industrial and geographical breakdown is being prepared and will be released in the near future.

The list makes a 72-page book (8½ × 11 pages) and two copies have been distributed to each exhibitor. Additional copies, if any are available, will be priced at $10.00 each because of the great cost.

ISA SPRING MEETING

The ISA Spring Meeting will be held May 12 and 13, at the Royal York Hotel, Toronto, Canada. Program data will be available shortly.

Hotel reservations should be made with Mr. G. R. Street, Convention Manager of the Royal York Hotel:

One person to a room......	$ 6.00	per day
Two persons to a room (Twin Beds)	$ 4.75	" "
Three persons to a room....	$ 4.25	" "
Four persons to a room....	$ 4.00	" "
Suites (Two persons)	$19.00	" "

Section News

BOSTON

The Boston Section held its third meeting of the season at 6 p.m. December 1, 1948 at the Boston Yacht Club, Rowes Wharf, Boston overlooking historic Boston harbor.

The after-dinner speaker Mr. P. A. Elfers, Vice-President and Sales Manager of the Fisher Governor Company was introduced by President E. R. Hoffman.

Mr. Elfers, a graduate of the University of Wisconsin, has had many years experience in the refinery and construction fields, he took as his subject "Liquid Level Control—Modern Construction and Application." The forty-five members present were very much interested in Mr. Elfers' talk.

The next meeting will be held on January 26, 1949, when Mr. J. A. Pellettere of the Gulf Oil Corporation will have as his subject: "Interconnected Control Instruments."

—James Condon, Corr.

CALIFORNIA

The annual meeting on January 4th, is important for the business of the Section, as well as for an excellent program this time. The business will consist principally of the report of the Election Committee, announcing the names of those who will be entrusted with the responsibility of conducting the affairs of the Section for the coming year. The speaker will be Dr. George Van Lear, of the Instrument Division of Lane-Wells Co. The pioneer commercial photo-electric "Pen Recording Raman Equipment" will be described and illustrated, and examples of its application will be presented. In general, Raman spectra are valuable for problems of molecular structure and constitution. With this equipment, industrial research laboratories can apply Raman spectroscopy to the rapid analysis of many organic and some inorganic solutions.

A special expedition to the Aerojet Engineering Corp. plant at Azusa has been set for January twelfth. We are to arrive at the plant not later than ten-thirty, and expect to be through by twelve-thirty. We will see the processing of the propellant for the standard Jato units, some test firings of these units, and the instrumentation connected with the test cells. Because of security regulations, it is necessary to know who plans to attend, and this trip must be restricted to members of the Section.

There will be a special joint dinner meeting of the American Society of Mechanical Engineers, The Southern California Meter Association. The Southern California Natural Gas Association, and the Instrument Society of America on Wednesday, February 9 at the Rio Hondo Country Club, which will be addressed by Major M. F. Behar, editor of Instruments Magazine, on "Fundamentals of Instrumentation."

CENTRAL INDIANA

The December 7th meeting was held in the auditorium of the Indiana Bell Telephone Co. Officers elected for 1949 are: J. B. Brill, President, Morris Underwood, Vice-President, and Henry Coffee Secretary-Treasurer. Following the business meeting a lecture-demonstration was given by E. C. Belzer, a representative of Indiana Bell. Mr. Belzer discussed some of the most recent advancements in telephony, as well as some of the earliest attempts in voice transmission.

In tracing the history of voice communication, Mr. Belzer related the progress made in many fields including metallurgy, chemistry, electricity, piezo-electricity and radio. He also discussed the most recent developments in the field of network broadcasting and television network broadcasting.

One of Mr. Belzer's most interesting exhibitions was lighting an electric bulb with a match and then blowing it out with his breath. This demonstrated the sensitivity of a Bell Laboratories invention, the "Thermistor", a device which prevents variations in the clarity of a long distance call regardless of variations in the temperature of the telephone wire.

Besides explaining the development of the telephone cable, one of the most important chapters in the history of the communications industry, he also explained the interesting role of quartz crystals in separating the hundreds of messages which may be carried over a single coaxial cable. These crystals are now grown commercially under controlled conditions.

The highlight of Mr. Belzer's talk was a display of the 'Transistor.' This amazingly simple device is housed in a tiny cylinder less than an inch long, yet it can do everything a vacuum tube can do and many other things besides. Two hair thin wires, touching a pinhead of a solid semi-conducting material soldered to a metal base are the principal parts of the 'Transistor.' When in operation it consumes less than a tenth of the power of an ordinary flashlight bulb. It is expected to be used to amplify telephone speech, to take the place of ordinary tubes in radios, and perform some entirely new functions.

The January 11th meeting will be held in Cropsy Auditorium at the Public Library. The speaker will be Mr. K. R. Geiser of the General Electric Co. and his subject will be "The Instrument Servo-Mechanism and Instrument Telemetering."

—E. E. Taylor, Corr.

CHICAGO

The December 6th meeting at the Builder's Club had as its scheduled subject "Industrial Applications of Electronics" by Lee Wilcoxon, Director of Electrical and Electronics Schools, Industrial Training Institute.

EASTERN NEW YORK

The annual dinner meeting was held on December 9, 1948, at the Circle Inn, Lathams Corners, N. Y., with over fifty members and guests attending. The business phase of the meeting consisted of the election of new officers and voting on amendments to the constitution. The newly elected officers are as follows:

President, W. J. Claffie, Jr., —Winthrop-Sterns Inc., Renss., N. Y.
Vice-President, Thomas Carse—Schiefer Electric Co., Albany, N. Y.
Rec. Secretary, J. H. Brandeau—Behr-Manning Co., Troy, N. Y.
Corr. Secretary, D. M. Wilsey—General Electric Co., Schenectady, N. Y.
Treasurer, R. N. Bushman—General Electric Co., Schnectady, N. Y.
Nat'l Director, G. Gardner—General Electric Co., Schenectady, N. Y.

Amendments voted on were to change the term of office of the officers from January 1st—December 31st, to July 1st—June 31st, and that the Executive Committee shall be composed of the officers of the section, the chairman of all standing committees, and the immediate past president. Both amendments were passed.

At this point, the meeting was climaxed by the introduction of the speakers for the evening. Seemingly, the meeting was a meeting of presidents inasmuch as Carl Kayan, President of The I.S.A. was in attendance to enlighten us as to the workings at the national office which are considerable as outlined by President Kayan. The information was of exceptional aid to the section members who were unable to attend any of the conferences.

The last, but by far not the least of the speakers was E. S. Lee, president of the A.I.E.E., who was our guest speaker for the evening. Mr. Lee's subject for the evening was "What's New in Electrical Instruments and Measurements." With this as his theme, he elaborated on the use of instruments and measurements and how they permeate not only our technical, but our personal living as well. He stressed the importance of measurements and spoke on the advancements of instrumentation and measurements through the past to the present.

A rising vote of appreciation was given both to President Lee and President Kayan for their fine talks and the meeting formally adjourned at 10:45 p.m.

W. J. Claffie, Corr.

KANSAS CITY

The Kansas City Section held its regular meeting on Tuesday, November 30th, at "The Crossroads." The guest speaker was Mr. John R. Green, Manager of the Steel and Ceramic Division, Brown Instrument Co., Philadelphia, Pa. Mr. Green's subject was "Radiation Pyrometers as Applied to Industrial Processes."

Mr. Green's talk, which was supplemented by slides, began with a review of the fundamental principles of radiant energy transfer which served as a background for a discussion of the application of these principles to Industrial temperature measurements. A comprehensive explanation of "Black Body and Non Black Body Conditions" was given. It was emphasized by Mr. Green that in temperature measurements, especially radiation type measurements, it is not always important nor desirable to know exact temperature. In radiation temperature measurements, according to Mr. Green, one of three types of measurement may be important, namely:

1. Relative temperature as compared to exact temperature.
2. Relative temperature only.
3. Change of physical state.

Slides depicting industrial applications illustrated the application of radiation pyrometers as a solution, in some cases the only solution, to problems requiring better means of measurements and automatic control. After a brief question period, the remainder of the meeting was devoted to a report from the nominating committee on their nominations for 1949 officers.

The nominating committee consisted of H. C. Van Smith, Loren Oberhelman, and Rheim Benninghoven. The committee's nominations were as follows:

President, W. J. Blackburn
Vice-President, Ralph Baiers
Secretary, S. L. Spies and George Haynes.

The following additional candidates were nominated from the floor.

President, Loren Oberhelman
Vice-President, Rhein Benninghoven

The Secretary was directed by the Section President to prepare and mail ballots to all members, enclosing self-addressed, stamped envelopes for return of the ballots. The ballots will be counted and results made known at the regular meeting, to be held December 14, 1948. A joint meeting with the Chemical Engineering Society, was held on December 14, 1948, at the University of Kansas City.

Mr. Vincent V. Tivy, Manager Refinery Instrument Sales, The Foxboro Co., Foxboro, Mass., presented an illustrated lecture on "Control Instrumentation For Process Industries." Mr. Tivy explained the fundamentals of Proportional Band, Automatic Reset and Rate-Action, and their effects upon process controls. The members thoroughly enjoyed Mr. Tivy's colorful presentation of his subject.

The officers elected for the year of 1949 are as follows:

President, W. J. Blackburn, Brown Instrument Co.
Vice-President, Rhein Benninghoven, Republic Flow Meters
Secretary, S. L. Spies, J. F. Pritchard & Co.

—W. A. Reichow, Corr.

LOUISVILLE

At the meeting on December 14th, the following officers were elected:

President, Pearce Grose, Tube Turns
Vice-President, Mel Johnson, B. F. Goodrich Chemical Co.
Treasurer, E. L. Rogers, E. I. DuPont de Nemours & Co., Inc.
Directors, Irving Lefkowitz, Joseph E. Seagram & Sons, Inc.; Estus Ballard, Joseph E Seagram & Sons, Inc.
Secretary, Howard Scherffries, Louisville Gas and Electric Co.

—Paul B. Smith, Sec'y

PHILADEPHIA

The December meeting was held Wednesday night, December 15th, at the Clover Room in the Bellevue-Stratford Hotel. This meeting was devoted to a "gadget contest" which had been run over the past month and awards were made as follows:

1st Prize—$20.00 to Amos Keeler, Socony-Vacuum Oil Co., Paulsboro, New Jersey on a novel sump level and float control.
2nd Prize—$15.00 to Wm. Lindsay of the Atlantic Refining Co., for a unique dam level indicator.
3rd Prize—$10.00 to J. Grant MacKay of Pennsylvania Salt Co., Philadelphia, Pa., for an ingenious electronic "Commercial" eliminator.
4th, 5th, 6th and 7th prizes of $5.00 each were awarded to J. Jackson of Socony for a propane bottle filling control system; C. L. Harrington of the DuPont Co., for a copper tubing straightening device; J. Ritter of Socony Vacuum for a jig for welding neck orifice flanges; R. Roseburg of Atlantic Refining Co., for a vibration-proof thermocouple.
Seven other awards of ISA pins were made to the following:
Frank Nestor of Pennsylvania Industrial Chemicals; E. Straing of Socony Vacuum; A. Hoffman of Socony; Lyman Allen of American Viscose; M. S. Carty of Socony-Vacuum; Fred Wetherill of American Viscose and Ralph Kimball of American Viscose.

The individual entries had been redrawn to poster size so that they were readily discernible by the audience and were explained in detail before the individual awards were made. The session proved to be a very interesting and amusing one, as well as profitable for the prize winners. Next month's meeting will be held January 19 at the Bellevue-Stratford Hotel.

John C. Koch, Corr.

PITTSBURGH

Over 70 members and guests gathered for dinner at the Roosevelt Hotel on November 22nd. There were an additional 6 present for the paper by Mr. F. E. Havrilla of Carnegie Illinois Steel Corp. on "Open Hearth Instrumentation."

The discussion and questions at the conclusion of his presentation indicated unusual interest in the problems of instrumentation as well as those of combustion.

Activity is continuing on the organization of an Inspection and Gaging Group. The Steering Committee has arranged the next meeting of the group for Tuesday, January 18th, when Mr. E. J. Abbott will speak on "Surface and Roughness Measurements."

On the evening of Monday, December 20th, 40 members and guests gathered for dinner before the monthly meeting. About 75 were present when the meeting started at 8:00 p.m. Chairman R. R. Webster of the Program Committee presented a tentative program for next year. National Secretary Dick Rimbach then told some of the plans for the '49 Conference and Exhibit in St. Louis and introduced his new assistant secretary, John McCaffery.

Mr. C. H. Barnard, of Bailey Meter Co. spoke on "Gas Analyzers." His talk dealt with the application of these instruments to combustion processes as employed in boilers, cement kilns, open hearth, glass tanks, petroleum furnaces, and continuous strip annealing furnaces. A lively discussion period followed with most of the questions dealing with cleaning up the gas sample before passing it to the instrument.

The next meeting will be held on Monday, January 24th, at the Roosevelt Hotel. Mr. J. Manuele, Director of Quality Control of Westinghouse Electric Corp., will speak on Quality Control and Instrumentation.

—M. M. Fromm, Corr.

ROCHESTER

The November 23rd meeting was held in the Bausch and Lomb Physics Building on the River Campus of the University of Rochester, Rochester, N. Y. Mr. Wilfred Howe, Director of Research of the Foxboro Co., Foxboro, Mass., was the speaker of the evening. Mr. Howe spoke on the subject, "Electronic Instruments."

(Continued on Page 81)

Valve Characteristics and Process Control*

By J. G. ZIEGLER and N. B. NICHOLS

FROM a construction standpoint, the simplest control valve is probably the single or double seated "Bevelled Disc" type, sometimes called "Quick Opening" or "Poppet" valves. They were probably the first type of valves used with automatic control devices since they are essentially globe valves with a sliding stem instead of the usual threaded type operated by a handwheel. Being a simple valve, it is easier to construct than the more complex types in common use nowadays; its simplicity is its principal claim to fame. It is essentially a low lift valve, requiring less lift than ported or shaped plug valves to reach a reasonable maximum capacity for passing the controlled medium.

But the bevelled disc valve has fallen into disfavor because it has essentially a linear flow-lift characteristic; the area of its effective opening increases in almost direct proportion to the lift of the disc from the seat. When such valves are used on *certain* processes, a non-linearity appears; control results are not equally good under different "load" conditions, load generally being expressed in terms of the valve opening necessary to maintain the measured variable at the required value. If, on these processes, the controller is adjusted to give optimum control under a low load condition that is with a small valve opening, it is found that excessive stability is realized when the process is operating under high load conditions. Fig. 1 shows the effect of this non-linearity. A proportional plus automatic reset controller operates a linear valve and the control under low load conditions shows optimum stability in recovering from a small disturbance or load change, indicating that the controller responses are properly adjusted. But on the right, a similar disturbance applied to the process when it is operating at high load shows a recovery curve that is too stable, even though the same controller settings are used. By increasing the proportional response sensitivity setting of the controller at this load, the dotted recovery curve could be obtained, but this setting would be excessive when the process returned to the low load condition and would result in sustained oscillation or "hunting". So the sensitivity could not be increased above the value required at the more difficult load condition. Unless the instrument is readjusted for each load, the control results will not be as good as they could be at any but the low load condition.

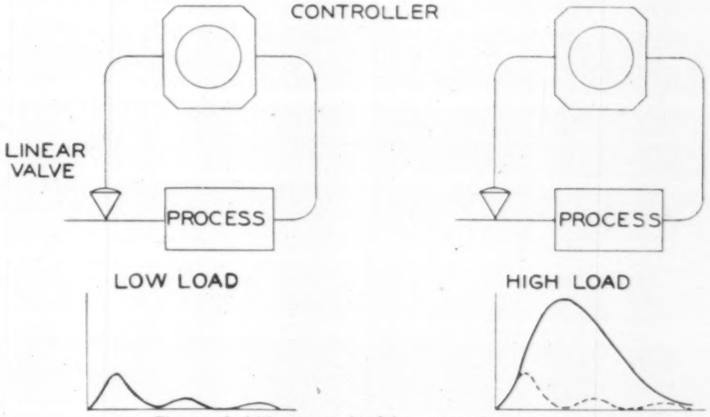

Fig. 1. Stability versus load in a control circuit.

In the control circuit of Fig. 1, the valve is linear, the controller response is linear but the process is non-linear. There are two rather obvious ways to correct the circuit even without altering the non-linear process. It is conceivable that another controller measuring the load could be installed and used to adjust the setting of the first so that the sensitivity is automatically increased with increasing load. This method has not been commercially used to any extent because it requires a more elaborate control mechanism than is generally justified. The same result can be obtained by leaving the controller linear, but altering the shape of the valve disc so that a given increase in lift at large openings makes more increase in flow than the same lift at low openings. This has the same effect as changing the controller sensitivity which is only a measure of the amount of valve movement resulting from a given pen movement, and valve movement only affects the process as it changes the flow of controlled medium to the process.

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The purpose, then of using a valve with characteristics other than those of a simple bevelled disc valve is an attempt to cancel the non-linearity of a process by means of a non-linear valve. If successfully done, the control circuit should have equal stability at all load conditions.

It is not practical to design a valve individually for each process because of the large variety of process non-linearities. Instead, valve manufacturers have attempted to standardize on a so-called "equal percentage" valve, which theoretically compensates for *one of the more common process non-linearities.* This characteristic is approached by a variety of valve plugs such as the various V ported and V notched types and the shaped plugs such as "ratio", "throttle" and "parabolic" types.

Acceptance of these "characterized" valves has been almost universal. They are used on all processes, linear and non-linear even though the equal percentage characteristic adds to the process non-linearity instead of correcting for it. The bevelled disc valve with all its structural advantages has been relegated to the position of the button shoe. On many of the less difficult control applications, the characteristic of the control valve used has very little effect one way or the other, but on the more difficult applications, some consideration should be given to the valve type if quality of control is important.

If only in the interest of improving control application we should develop some simple rules to be used as guides in valve selection. This paper attempts to evolve those rules. But first it will be necessary to "tool up" with a little control theory to simplify the analysis and keep us from relapsing into generalities.

Process Response Curve

One of the simplest yet most useful methods of process analysis is that of approximating the process response curve or reaction curve and using two of its most important dimensions for

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Note: Statements and opinions advanced in papers are to be understood as individual expressions of their authors and not those of the Society.

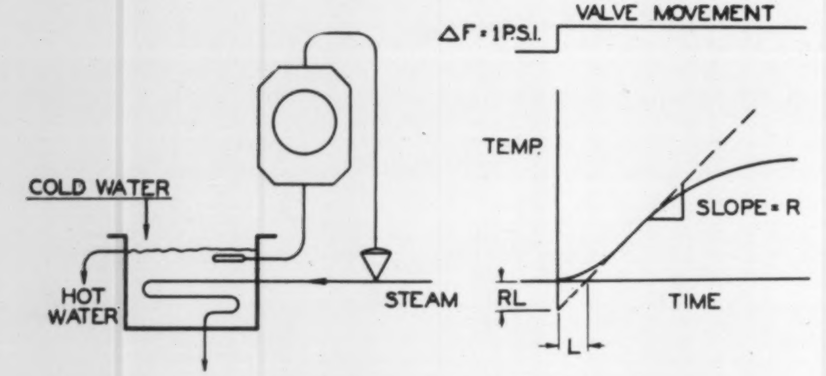

Fig. 2. Temperature control process.

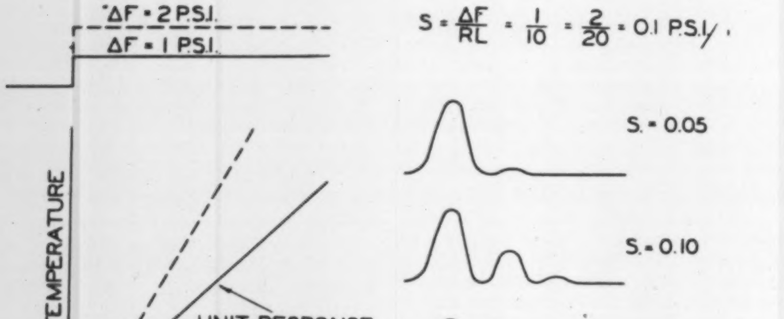

Fig. 3. Effect of proportional sensitivity adjustment.

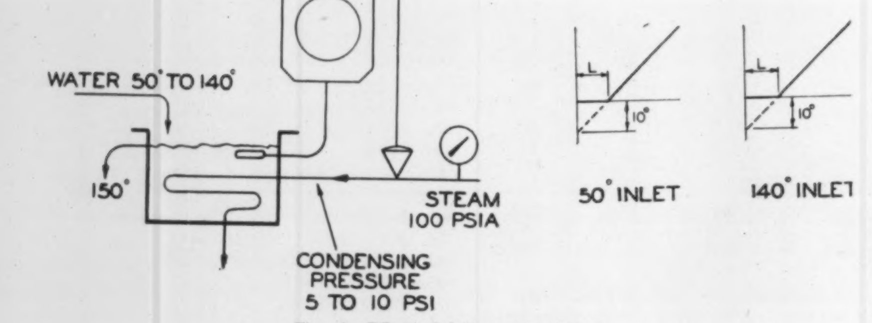

Fig. 4. Effect of inlet temperatures.

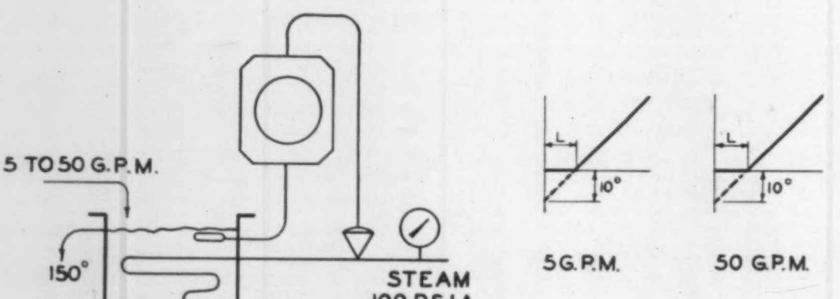

Fig. 5. Effect of inlet flow rates.

predicting the controller settings and the control results obtainable. Let us briefly review the method (1)[*] (2) (3).

If, when a process is under stable control with the valve in exactly the right position to satisfy the process demand and hold the instrument pen at the correct value, the valve is removed from the dictates of the instrument and suddenly moved to a different opening and held there, the new flow of controlled medium will cause the pen to draw a "Process Response Curve". Consider the process of Fig. 2 in which water flows through a tank and is heated by a steam coil to a controlled temperature. Enough steam is flowing through the partially open valve to maintain the tank temperature at a constant value. Suddenly the valve is opened slightly by making a sustained change of one psi on the diaphragm motor. More steam flows to the heating coil and the water temperature rises; the controller pen traces an S shaped curve as shown in Fig. 2. This curve is the process response curve and is generally too complex mathematically to allow easy analysis. The approximation referred to above consists in drawing a straight line tangent to the point of inflection of the curve and saying that the process is adequately represented by the simpler curve consisting of a dead period lag, L, and a "Reaction Rate", R. The fact that the actual process response curve levels out eventually at a new value (self-regulation) while the straight line does not, is of very secondary importance in the control analysis and can be disregarded. Thus, it can be said that the process shown in Fig. 2 is chacterized by an effective dead period lag of L minutes and that for a one psi change in pressure to the diaphragm motor the pen deviates at a maximum rate of R inches per minute.

If, as shown in Fig. 2, the sloped line of the approximated Process Response Curve is dropped back until it intersects the temperature axis, the intercept is the product of R and L or the distance which the pen travels in a time equal to L. This intercept is indicative of the controller sensitivity required for stable control. If the instrument is set so that it gives a valve movement equal to $\triangle F$ for the pen movement of RL degrees, stable control will result. In other words, the sensitivity will be equal to $\triangle F/RL$. Putting numbers on these quantities, suppose that L was one minute, R was ten degrees per minute and that the valve change initiating the response curve was one psi. The RL intercept would be ten degrees so the controller sensitivity would be set to give one psi change in output for each ten degrees of pen movement, or 0.1 psi per degree.

LINEAR PROCESS

Fig. 3 shows the Response Curve approximation for the process of Fig. 2, following one psi change in valve position. Dotted on the same figure is a similar curve that would result from a two psi change in valve position; it evidences the same lag, but twice the increase in steam flow causes the temperature to change twice as fast. The RL intercept of 20 degrees for a two psi change in valve position still indicates that the same controller sensitivity of 0.1 psi per degree should be used. Most processes evidence this type of linearity at least within limits. It is generally convenient to speak of a "Unit Response Curve", the one produced by the unit valve movement. Dividing the ordinates of the dotted curve of Fig. 3 by the two psi valve change makes it coincide with the solid line produced by a unit (1 psi) valve change. In the same manner, a 1/10 psi change in valve position could have been made, and the result multiplied by ten to produce the same Unit Response Curve. This would be a much better method if the process were non-linear.

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[*] Numbers in parentheses refer to similarly numbered references in bibliography at end of paper.

Many non-linear physical phenomena behave in a linear fashion when subjected to only small disturbances from an equilibrium condition. A process, for example, can be quite linear when subjected to small changes or increments in valve position from that required to supply the load and still be quite non-linear when subjected to large disturbances. The linear theory of control can obviously be applied to a process of this type and the conclusions reached will be valid as long as no large disturbances are encountered. We may then describe the incremental process behavior in terms of the incremental process characteristics. A common method of determining the incremental unit reaction rate is to make a tiny change up and down from the equilibrium value and average the two unit reaction rates thus obtained. The incremental process lag would be similarly obtained.

Returning to Fig. 3, the Process Response Curve showed the required controller sensitivity to be 0.1 psi per degree. With a setting thus determined the recovery curve of the controlled process would have adequate stability with an amplitude ratio of approximately 0.25. Increasing the controller sensitivity to 0.2 would cause instability while reducing it to 0.05 psi per degree would give excessive stability.

Now we are tooled up. It is quite possible that the process of Fig. 2 could be linear, and if a linear valve were used, equal stability achieved under all operating conditions. In order to check it for linearity we need only plot a Unit Response Curve at various load conditions. If, as noted on Fig. 4, the only load change on the system was caused by varying inlet water temperature, the unit response curve at low load (warm inlet) and high load (cold inlet) would be identical provided that the pressure drop over the steam valve remained essentially constant. This would be entirely true if the condensing pressure in the coils were less than half the steam supply pressure at the high load condition.

Under these conditions, since the unit response curves are identical, the linear valve is ideal for the process and would give equal stability at all loads between minimum and maximum.

Instead of variations of inlet water temperature, the major load change on our process might be changes in water flow as shown on Fig. 5. The volume of water and consequently the heat capacity of the tank remains constant so a given increase in steam flow should start to raise the temperature at the same rate regardless of water thru-put. Again, the process is linear so that a linear valve should be used.

Suppose that the water flow was essentially constant and the inlet temperature as well, but the major change in load was variation in the steam supply pressure between 25 and 100 psi. This is a load change since it requires a change in valve position if the water temperature is to be maintained constant. Referring to Fig. 6, it can be seen that the two unit response curves at maximum and minimum loads are no longer identical; at lower steam pressure, the reaction rate is lower giving a smaller RL intercept, and indicating that a higher controller sensitivity can be used at this load.

It is easy to see why the unit response curves are different at each load condition. If a unit increase in valve opening caused a ten degree per minute rise in tank temperature with the steam supply at 100 psia, the same increase in valve area with 50 psia steam should only change the steam flow half as much and result in only five degrees per minute rise of tank temperature.

So our process, which was beautifully linear before, has become non-linear, and the evidence indicates that the reason is somehow connected with the type of load change. When the steam pressure was constant so that each position of the valve called for a definite flow of steam, the process as a whole was linear in spite of large load changes at other points in the process. But as soon as different valve openings were required to pass the *same* quantity of steam an ugly non-linearity confronted us. At least we have unearthed one clue to the problem of process non-linearity; the sketch of our process as shown in Fig. 2 tells us nothing about process linearity or lack of it. We must consider the relative magnitude of the various load changes which can afflict the process.

The process of Fig. 6 can be made

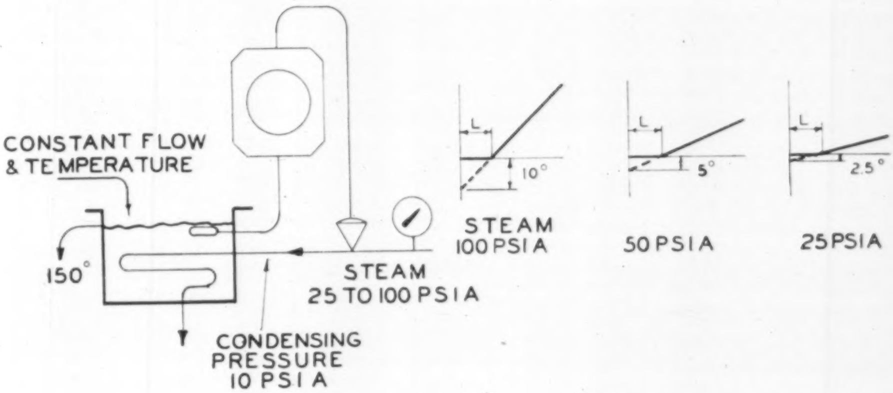

Fig. 6. Effect of pressure drop across a linear valve.

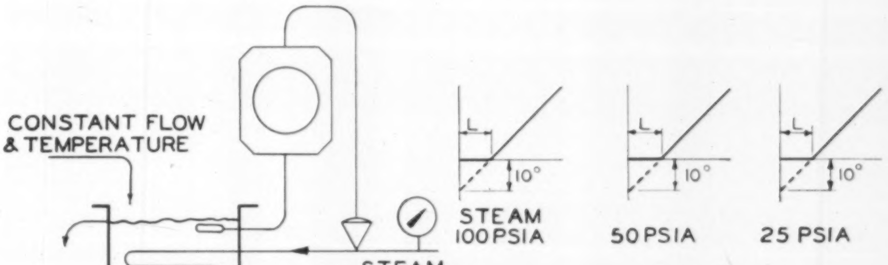

Fig. 7. Effect of pressure drop across an equal percentage control valve.

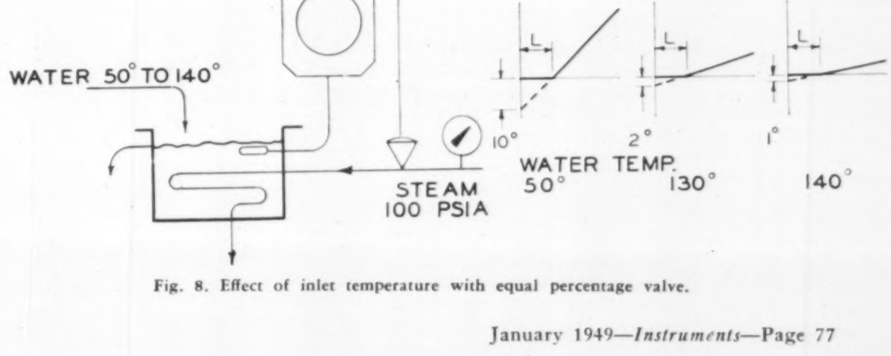

Fig. 8. Effect of inlet temperature with equal percentage valve.

linear with respect to load by substituting an "equal percentage" valve for the linear one, as shown on Fig. 7. If a unit lift gives a ten degree per minute change in tank temperature when the steam pressure is 100 psia, it should produce the same rate of rise when the steam pressure is 25 psia because the open area of the valve is four times as great and the disc is so shaped that the same unit lift makes four times the change in area. The valve derives its name from this "equal percentage characteristic"; a given lift at any opening increases the area a fixed proportion of the existing area.

LINEAR PROCESS WITH NON-LINEAR VALVE

Now we are in a position to see the mistake of using "equal percentage" valves willy-nilly on all processes without regard for the linearity or lack of it which the process exhibits. In Fig. 8 we see the effect of using an equal percentage valve on the process of Fig. 4 where the major load change was due to variation in temperature of the feed water from 50 to 140 degrees. This represents a 10 to 1 change in load if the water is heated to 150 degrees as shown.

It is easy to see that the controller sensitivity would be determined at the high load condition, that is, with 50 degrees feed temperature calling for a large valve opening, since this response curve would have the largest RL intercept under these conditions. At lower loads, the process is still linear, but a unit change in valve position does not make nearly as much change in steam flow due to the shape of the equal percentage disc. The control stability would therefore increase with decreasing load until at minimum load with 140 degrees feed water it would be ten times as stable as necessary. In other words, the control would be only one-tenth as good as it should be at this load. Under no circumstances should an equal percentage valve be used on the process when the load changes are those given in Figs. 4 and 5, because such a valve would change a nice linear process into a very non-linear one.

TWO TYPES OF LOAD CHANGE ON THE SAME PROCESS

It should be interesting to attempt to linearize a process having two sources of load change, one calling for a linear valve and one for an equal percentage valve. The process shown on Fig. 9 is subjected to a feed water temperature change from 110° to 140° making a four to one load change with the outlet temperature at 150° and calling for a linear valve. The steam supply pressure also changes from 25 to 100 psia, making a four to one load change calling for an equal percentage valve. The adjoining response curves clearly show that the linear valve is correct for any feed temperature as long as the maximum steam pressure is applied, but that it allows excess stability at lower steam pressure. The equal percentage valve keeps a constant stability for changing steam pressure as long as the feed water load is at a maximum, but the stability becomes excessive at higher feed temperatures. Each valve is equally bad when it attempts to correct for the wrong process non-linearity. It might appear that a valve characteristic could be devised which would linearize the system completely, but this is not the case. When more than one type of load change occurs in the same process, *there is no ideal solution,* and the choice of valve characteristics must be a compromise. In the above example where both load changes are of equal magnitude, either valve could be used and the only reason for choosing one type over the other would be on a basis of mechanical or structural characteristics, or possibly on availability.

Often, in situations such as this, when two types of load changes are encountered in the same process, the load changes are of widely different orders of magnitude and the valve is selected that has the characteristics which will linearize the *major* load change. For example, if all the load changes so far considered came into the process, that is, feed water flow from 5 to 50 gpm. at a temperature between 50° and 140° and steam pressure variation between 25 and 100 psia, the choice would be easy. A linear valve should be used because the water flow and temperature changes together amount to a load change of 100 to 1 and call for a linear valve, while the steam pressure range is only four to one in favor of the equal percentage valve. It would be a mistake to leave this example without pointing out that the addition of a steam pressure reducing valve, set for 25 psia, placed ahead of the linear control valve would eliminate the source of the non-linear load change on the process and perfect linearity would result as in Figs. 4 and 5.

MISCELLANEOUS NON-LINEARITIES

Some processes exhibit non-linearities of a more complex nature than the ones considered above (4). One of these is line drop. If, in the process which we have been using as an example, the only load change was one calling for a linear valve and the steam pressure was constant, but there was a long line between the source of constant pressure and the control valve so that when the steam flow to the process was high, some of the pressure drop shifted to the line, a non-linearity would exist. At zero flow the control valve takes the entire pressure drop, but as it opens wider, the supply pressure at the valve drops off. A quick glance at the problem might produce the conclusion that an equal percentage valve would correct for this non-linearity, but this is not the case. Peters (5) has explored this problem and shows that each individual case requires its own solution. We have already noted that it is usually uneconomical to try and develop valves with special characteristics for isolated non-linearities. Generally, time spent on such an endeavor could better be used in exploring the process for possible reduction in time lag or elimination of some of the load changes (6). The best solution to the "line drop" problem is to increase the line by one or two pipe sizes so that the valve takes practically all of the pressure drop, or install a pressure reducing valve ahead of the control valve.

A similar non-linearity would appear in our process if the pressure drop over the control valve were less than critical, that is, the condensing pressure in the heating coil greater than half the upstream absolute pressure. In previous examples we have assumed a low condensing pressure relative to the steam supply ahead of the valve so that changes in condensing pressure made no difference in the steam flow thru the valve at a given opening. If, on the process, the load changes called for a linear valve and the steam supply pressure was constant, but the condensing pressure could approach the supply pressure at high loads, excessive stability would be evidenced at high loads since a lower pressure drop would exist over the control valve. This non-linearity could be reduced if the valve were made to open more for a given increase in lift at large openings and this would appear to call for an equal percentage valve at first glance. But, careful consideration shows that each such case

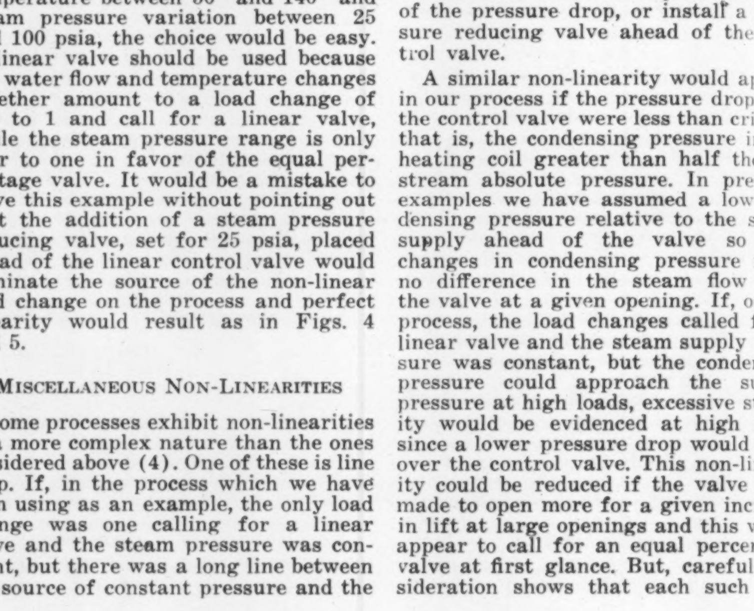

Fig. 9. Comparison of equal percentage and linear valve.

would be a special one, since the relationship between condensing pressure and steam flow would not be matched by an equal percentage valve. It is probably better to use a linear valve if it is called for by the major process load change and reduce the non-linearity by increasing the heating surface of the steam supply pressure so as to maintain a fairly uniform pressure drop over the control valve.

EXAMPLES

In the process which we have thus far used as an example it appears that the equal percentage valve should be used only when the major process load change consists of variation in steam supply pressure. In order to formulate a more general rule governing the application of these valves, let us consider a few other processes.

Fig. 10 shows a gas fired oil heater, the object being to maintain a constant outlet oil temperature by operating a valve in a fuel gas line to the burners. Some of the possible load changes on the system would call for a linear control valve; some for an equal percentage valve. Changes in oil flow, its incoming temperature, its outlet temperature and its heat capacity would call for a linear valve. Similarly, variations in heat loss from the furnace due to the surrounding air temperature would be more or less linear as well as variations in the condition of the heating surface calling for higher fire side potentials as the coefficient of heat transfer decreased. Variations in supply pressure of the fuel gas would call for an equal percentage valve as well as changes in the calorific value of the gas. This last point indicates that our rule regarding non-linear load changes calling for equal percentage valves can be extended beyond mere supply pressure changes to include any change which alters "the quantity of priceless ingredient (in this case BTU) which the control valve passes at a *given* opening".

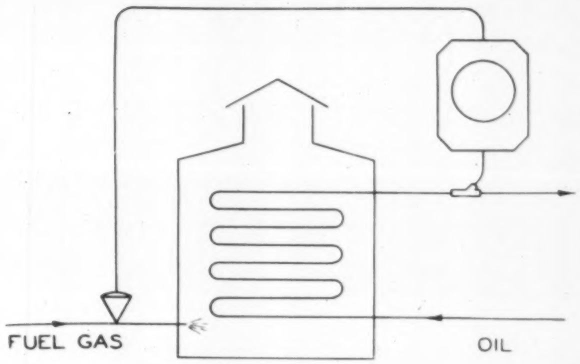

Fig. 10. Gas-fired oil heater.

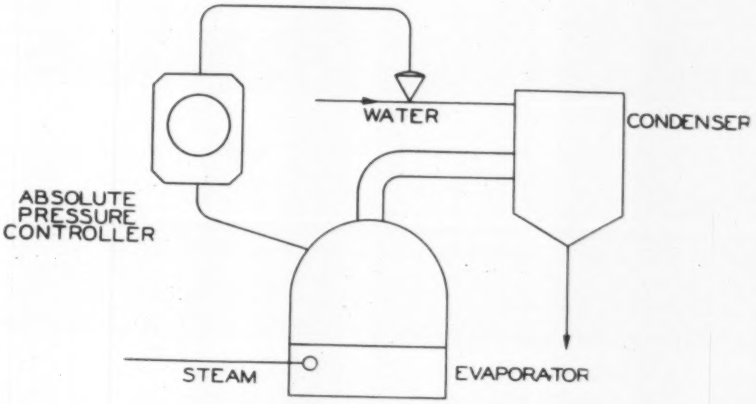

Fig. 11. Absolute pressure control.

A parallel example to the one above is shown in Fig. 11. In this case the controlled medium is water to a condenser so that any change in cooling ability of the valve, change in supply water temperature or change in the pressure drop over the valve, would call for an equal percentage valve while changes in the flow of vapor to be condensed would call for linear characteristics. The major load change is generally the linear one on this application.

Another typical application, liquid flow control, is diagrammed in Fig. 12. Historically, this was probably the application under consideration when equal percentage valves were first designed because about the only load change that can possibly affect this process is variation in the pressure drop over the valve, at least when the required value of flow is constant.

The unit response curves under case 1 and case 2 of Fig. 12 show the effect of a four to one change in the pressure drop over the control valve which, due to the square root relationship of flow to pressure drop, is equivalent to a two to one change in load, i.e. valve area. The equal percentage valve gives the same stability under both load conditions and should be used in place of the linear valve, which would give twice the stability under the low pressure drop condition.

If, however, the pressure drop over the valve remained essentially constant, but the desired flow changed by a factor of two to one, a different type of load change is introduced. Since the flow meter responds linearly to pressure drop over the orifice plate which varies as the square of the flow, a given flow change at one hundred gallons per minute produces only one-half as much pen movement as the same flow change at 200 gpm. Comparing the behavior of the linear valve under the case 1 and case 3 conditions shows a two to one increase in stability at the low flow. The equal percentage valve working at

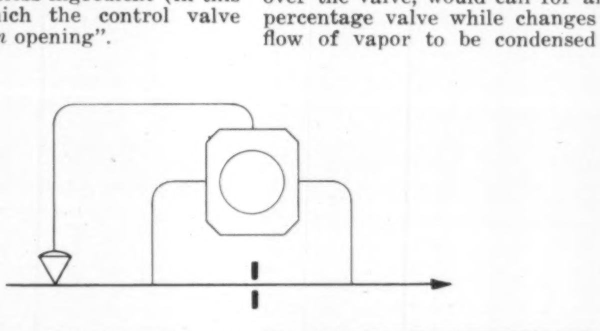

Fig. 12. Flow control.

half the original opening makes only half as much flow change for an increment of lift and produces a four to one increase in stability at low flow. The same comparison exists between cases two and four at the lower pressure drop.

This indicates that, on flow control, the equal percentage valve is to be preferred if the major load change is in the pressure drop over the control valve rather than changing flow requirements. On the other hand, a linear valve is indicated if the set point is changed materially, but the pressure drop is reasonably constant. In this connection, note that a considerable change in pressure drop may not constitute much of a load change since the flow only changes as the square root of the pressure drop over the valve. A two to one change in pressure drop is only equivalent to a 1.4 to 1 load change. Generally, load changes of less than two to one do not warrant consideration of valve type.

It should be noted in connection with the flow control dilemma that there is again no ideal solution to the problem if both the pressure drop and the required flow change. Use of a linear type flow meter in which the pen movement is proportional to flow instead of differential pressure over the orifice, makes the circuit linear for changing flows when a linear valve is used. Under these circumstances, the equal percentage valve is wrong in that it gives more stability at low flow conditions.

It can be seen from the above flow control example that the use of equal percentage valves does not necessarily guarantee equal stability under all conditions even though the major load change calls for these characteristics. The only sure way to check process nonlinearity is to plot unit response curves for each of the conditions under which the process must operate. Still, the "Priceless Ingredient" rule is a good criterion for the load changes calling for equal percentage control valve characteristics and is worth re-stating.

"Use of an equal percentage valve on a process is indicated if the major load change on the process is one which alters the quantity of priceless ingredient which the control valve passes at a given opening".

THE PRACTICAL SIDE

So far, this paper has attempted to show the reason for considering valve characteristics and to clearly distinguish between the process load changes calling for equal percentage valves and those on which linear valves are most desirable. Sometimes considerations other than those of linearizing a process weigh more heavily in the final choice of a control valve; it will be necessary to note some of these before we are able to select the best valve for a given job.

Mechanically, the linear bevelled disc valve has quite a few advantages over the various equal percentage valves. Structurally, it is simpler, requires less machining and is generally somewhat less expensive than other types. It is more symmetrical in its construction than the V notched types and consequently seems to resist localized erosion of the seats and discs which appears in the latter type due to the flow streams being concentrated by the notches. The "ratio plug" valve, the only equal percentage type which maintains those characteristics between fairly wide limits, has a distinct weakness in the close clearances and low closing angle and should only be used to regulate flow of controlled mediums which do not deposit scale or carry suspended solids. A slight scale deposit or solid particles caught between the seat and plug can jam the valve as it closes. Even the V notch and modified ratio (parabolic) plug valves should be used with caution if solids are present in the controlled medium.

Another advantage of bevelled disc valves over other types is that less lift is required than on ported and plug types of the same size. This often allows the use of smaller diaphragm motors and this, coupled with the smaller stroke, results in a valve which can be moved from one opening to another more rapidly with a given instrument relay valve capacity. This reduction in valve lag can materially improve those processes in which valve lag plays an important part such as many level control, pressure control and flow control applications and simple "mixing type" temperature control circuits. The use of smaller diaphragm motors and shorter lifts can be a disadvantage if equal valve friction is present as it can cause greater frictional dead spots to be present in the control circuit than if longer lifts and more powerful motors were used. However, on any control application, difficult enough and important enough to warrant consideration of valve characteristics, a valve positioner should be used for elimination of the frictional effect.

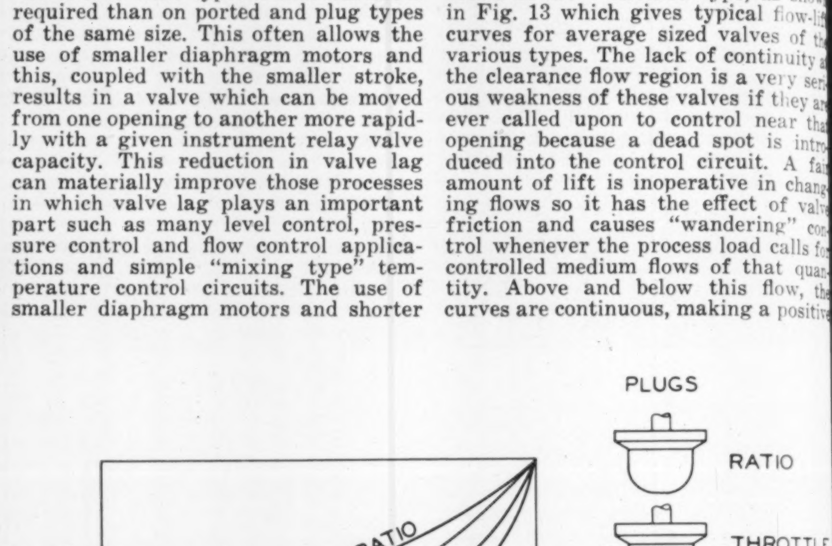

Fig. 13. Valve characteristics.

Actual experimental curves of flow versus lift for equal percentage valves show considerable deviation from the theoretical characteristic (4). This is not surprising in view of the extremely small machining tolerances that are required to hold the equal percentage characteristics down to small values of flow. The smaller the valve, the more difficult it becomes to maintain the desired curve at small openings. On large valves, six inches and over, it is conceivable that fair adherence to the equal percentage curve could be obtained down to perhaps 5% of maximum flow; 15% would be a realistic figure for valves of one inch size and smaller. Below these values the clearance between plug and seat ring is too small for good mechanical operation of the valve so the plug is relieved to maintain a reasonable minimum clearance down to the point at which tight closure is achieved by the bevelled portion of the plug meeting the seat. This makes the valve operable mechanically, but it leaves a discontinuity in the valve characteristic curve as shown in Fig. 13. In the region of this clearance flow, very little change in flow occurs in that portion of the valve lift where neither the shaped plug or the bevelled portion of the plug is changing the free area.

This discontinuity is characteristic of all shaped plug valves and is also found in the V notched type, as shown in Fig. 13 which gives typical flow-lift curves for average sized valves of the various types. The lack of continuity at the clearance flow region is a very serious weakness of these valves if they are ever called upon to control near that opening because a dead spot is introduced into the control circuit. A fair amount of lift is inoperative in changing flows so it has the effect of valve friction and causes "wandering" control whenever the process load calls for controlled medium flows of that quantity. Above and below this flow, the curves are continuous, making a positive change in flow for every valve movement. It should be noted that unlike valve friction, this discontinuity cannot be eliminated by a valve positioner.

The clearance flow discontinuity puts a very severe sizing limitation on equal percentage valves because they should only be called upon to control at higher flows. In applying these valves to processes having a wide range of loads it is necessary to size them very carefully to insure that they always operate at openings above the discontinuity. By reference to Fig. 13 it can be seen that at best these valves are only good over a twelve to one change in load and if some allowance is made for the fact that it is bad practice as well as next to impossible to size a valve so that it just carries maximum load at full opening, a reasonable usefulness of these valves might be taken as an eight to one range of load. Possibly fifteen to one on large valves but nearer five to one on small valves. The bevelled disc obviously has no discontinuity in its flow lift curve.

Many control applications are not subjected to severe or wide load changes; sometimes this is due to the fact that the equipment under control will simply not operate at widely differt loads. For example, the tolerable nits between maximum and minimum por velocity in a sieve plate fractioning column are seldom much over two one. Below half the maximum velocy, liquid falls thru the plates. Ineasing use of automatic control in instry tends to make each control job sier. With practically all variables ntrolled on a fractionating column, ds may not vary over ten percent ther way on most of the control circits. On those many processes which not have a range of load greater an two to one, it is scarcely worth nsidering valve characteristics at all nce the non-linearity introduced by ing the wrong valve will not have a ticeable effect on the control results.

Likewise, there is little reason to nsider valve characteristics on applitions involving low reaction rates hich will operate in high values of ntroller sensitivity. These include mperature control of large liquid lumes, most level control and many essure control applications. On these sy circuits the pen deviations are nerally so small that time spent in nalyzing for process linearity is not epaid by appreciable improvement in ntrol performance. There is no definte border line of controller sensitivity elow which consideration of valve charcteristics is justified, the easier the b in this respect the less need for using ne type over another.

By the same reasoning, applications nvolving short lags even though reacon rates are high, will have a short period of oscillation. The sensitivity may be low, but the short period with its accompanying high automatic reset rate insure quick recovery of the process following a load change. On these easy processes which include mostly pressure, flow and level control, and those temperature applications in which two streams at different temperatures are mixed, the control results are generally so good due to the inherent quick recovery that there is little point in worrying about valve characteristics.

If the thoughts brought out in this paper are set down in a logical order they form a simple guide for quickly determining the most desirable control valve for a given application.

A. DON'T BOTHER TO CONSIDER VALVE CHARACTERISTICS IF:

1. The controller sensitivity will be high, or
2. The period of oscillation will be short, or
3. The maximum range of load is less than two to one.

B. DON'T CONSIDER THE USE OF AN EQUAL PERCENTAGE VALVE IF:

4. The controlled medium carries solid particles or will deposit scale, or,
5. The maximum range of loads is greater than about eight to one, or,
6. The major load change calls for a linear valve, or,
7. The valve lag accounts for most of the effective process lag.

C. CONSIDER THE USE OF AN EQUAL PERCENTAGE VALVE IF:

8. The major load change calls for an Equal Percentage valve and none of the conditions under B apply.

This paper has attempted to point out that some automatic control circuits can be made more linear by the use of non-linear valves, but that careless application of such valves can do more harm than good from the standpoint of control results. It is hoped that the paper will clear away some of the mystery and half truths that have always surrounded the subject of valve characteristics and lead to more rational selection of valves for controlled processes.

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(Continued from page 74)

The speaker first described briefly the arious electronic instruments available n the market. The several DC and AC ndicating, recording and controlling elecrical and electronic instruments were numerated from the standpoint of type of onstruction, basis of operation and intended use. Mr. Howe pointed out the various roblems and questions to be satisfied in he design and development of the Foxoro DC Dynalog which operates on the rinciple of variable capacitance. The elecronic and mechanical advantages of this nstrument over other self-balancing instruments was also pointed out.

The speaker continued with a discussion f the uses of electronic instruments in ndustry. He compared the use of electronic quipment with pneumatic instruments and ave reasons why he considered electronic quipment superior in certain instances, ointing out that most of the electronic nstruments installed in industrial plants oday are used for measuring temperature. This led to a discussion of why electronic nstruments were chosen for specific applications mentioned by members of the audience.

Mr. Howe concluded his talk by describing specific instruments and applications n reply to questions asked by members f the group. The business meeting included introduction of visitors and guests and a discussion of a revision of the constitution which was voted upon. The next meeting, December 14, will feature a talk on "pH measurement and Control" by Dr. E. D. Haller of National Technical Laboratories, Pasadena, California. A slate of officers will be presented by the nomination committee and nominations will be made from the floor at the meeting in preparation for the January election of officers.

—Charles W. Covey, Corr.

SAINT LOUIS

The St. Louis Section ISA held its regular meeting on Thursday, December 2, 1948, at the Engineers' Club in St. Louis. This was a joint meeting with the St. Louis Engineers' Club and the Institute of Radio Engineers, and was addressed by Dr. Joseph A. Becker of the Bell Telephone Laboratories.

The talk was titled "Recent Developments in Semi-Conductors and the Transistor." Dr. Becker described the experiments leading to the development of this device, which consists of a crystal of a semi-conductor, mounted in a small capsule about ½ inch long, upon the surface of which are two "cat-whisker" contacts, spaced a few thousandths of an inch apart. One of these connections is called the "emitter" and the other the "collector." When a signal is applied between the base (to which the crystal is grounded) and the emitter, an output voltage 20 times larger may be obtained in the output circuit of the collector. Thus the device may be used as an amplifier component, replacing the vacuum tube. It may also be used as an oscillator. The power output, however, is much smaller than that available with vacuum tubes, being of the magnitude of milliwatts.

Dr. Becker demonstrated the device by means of a radio set using only Transistors, also a public address amplifier employing them. Also demonstrated was a "Thermistor" which changed resistance with temperature so that a glow lamp was lighted by holding a match to the device, and extinguished by blowing on it. A semi-conductor coated on a wire was used to demonstrate the negative change of resistance with temperature change. An oscillator was demonstrated, with which musical tones were produced by depressing buttons. The two element device (diode) was used as the detector in the radio set, as it is very efficient as a rectifier. Absence of heat-up time was illustrated.

—Henry E. Zeffren, Corr.

WASHINGTON

The December 20th meeting was held in the auditorium of the Potomac Electric Power Co. Mr. R. E. Hadady of the American Instrument Co., of Silver Spring, Md., spoke on "General Instrumentation Methods for Moisture Measurements." Mr. C. E. Ohlheiser of the American Instrument Co., spoke on "The Aminco-Dunmore Electric Hyprometer and its Application" and Mr. H. K. Howerton of the American Instrument Co., spoke on "The Aminco-Weaver Water Vapor Indicator and Some New Uses." Both slides and demonstration equipment were used effectively, and a large amount of interesting and worth while information was presented.

The yearly business meeting was held prior to the presentation of the three speakers. The results of the election of officers were given and the new officers were presented.

Mr. O. E. Patton becomes President, succeeding Mr. W. A. Wildhack. Mr. R. G. Quick becomes First Vice-President, succeeding Mr. V. E. Patton. Mr. R. E. Hightower becomes Second Vice-President, succeeding Mr. E. L. Deeter, who has taken a position with the University of California at Albuquerque, New Mexico. Mr. R. L. Goetzenberger retains the position of National Delegate, and Mr. Edwin G. Brown becomes Corresponding Secretary, succeeding Mr. G. M. Rolls.

—Raymond E. Miller, Corr.

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Atlanta: Emory W. Clark, P. O. 819, Atlanta, Ga.				
Baltimore: Felix Cox, Bethlehem Steel Co., Sparrows Point, Md.		2 Fri.		
Boston: C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.				
California: D. D. Taylor, 234 E. Colorado, Pasadena 1, Calif.		1 Tues.	6:45	
Central Illinois: T. A. Carroll, 721 Hurlburt St., Peoria, Ill.				
Central Indiana: M. Underwood, 1235 W. 33rd St., Indianapolis, Ind.		1 Tues.	X	7:30
Charleston: Albert H. Hix, 1529 B Dixie St., Charleston 1. W. Va.		1 Mon.	X	8:00
Chicago: Floyd E. Erstman, 506 S. Wabash Avenue, Rm. 611, Chicago 5, Ill.		1 Mon.	6:30	8:00
Cincinnati: Smith Hickenlooper, 1147 Beverly Hills Dr., Cincinnati, Ohio.		4 Mon.		
Cleveland: L. W. Waldrip, 3030 Euclid Ave., Cleveland, Ohio.		4 Wed.	6:30	8:00
Cumberland: Clyde Babst, P. O. Box 447, Cumberland, Md.		*Tues. after 4 Mon.*	6:30	8:00
Detroit: T. S. Cawthorne, 570 Maccabees Bldg., Detroit 2, Mich.		3 Tues.		
Eastern New York: Wm. J. Claffie, Winthrop Chemical Co., 33 Riverside Ave., Rensselaer, N. Y.		1 Tues.	6:30	
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Philadelphia: C. W. Wood, 6908 Market St., Upper Darby, Pa.		3 Wed.	X	
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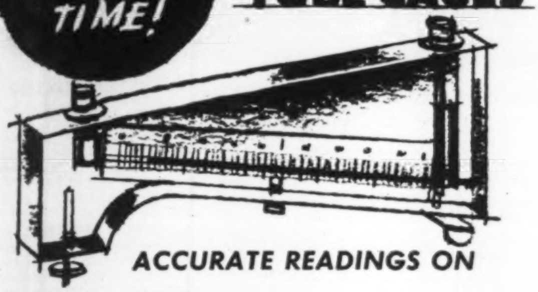

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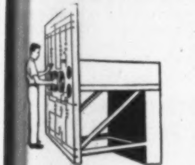

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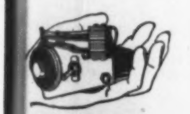

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R-21 "THE GENERAL RADIO EXPERIMENTER." 8-page Vol. 13 No. 3 issue of this house organ features article titled: "The Type 1670-A Magnetic Test Set," and miscellany section.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

R-22 ELECTRICAL ANGLE METERS. 4-page bulletin describes maker's "Model 311-A" R-F Z-Angle meter, said to simplify measurements heretofore made with cumbersome apparatus. Used for general laboratory applications, measurement of broadcast antennas and transmission lines, etc. —Technology Instrument Corp., 1058 Main St., Waltham 54, Mass.

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R-24 "BIDDLE INSTRUMENT NEWS." 4-page Vol. 4 No. 4 issue of this house organ features article on "TTR" transformer turn ratio test set; includes article on dielectric absorption test sheets.—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

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R-27 "THE OSCILLOGRAPHER." 16-page Vol. 10 No. 4 issue of this house organ features article titled: "A New, Versatile Oscillograph for the Cathode-ray Oscillograph," with bibliography included.—Allen B. DuMont Laboratories, Inc., Instrument Div., 1000 Main Ave., Clifton, N. J.

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R-31 INDUSTRIAL INSTRUMENT SELECTION GUIDE. 16-page Bulletin 98170 describes and illustrates maker's instruments for temperature, humidity, pressure, flow, liquid level, force, time cycle, etc.; also describes the jobs to which each type of instrument is suited, and how it reacts.—Taylor Instrument Companies, Rochester 1, N. Y.

R-32 FIXED COMPOSITION RESISTORS. 12-page Bulletin B-1 gives data on characteristics and specifications of new "Type BT" insulated fixed composition resistors available in ratings from one-third watt to two watts.—International Resistance Co., Philadelphia 8, Pa.

R-33 SWITCHGEAR AND CONTROL DEVICES. 16-page guide describes and illustrates rotary control switches, push button stations, generator voltage regulators, synchro-operators, current and potential transformers, etc. Types and ratings supplied on various equipment; standard wiring diagrams accompany data.—Allis-Chalmers Mfg. Co., S. 70th St., Milwaukee, Wis.

R-34 "THE CAPACITOR." 16-page Vol. 13 No. 12 issue of this house organ contains article titled: "Testing A-c. Motor Starting Capacitors"; and "Trading Post" section for selling, buying, and swapping propositions. — Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

R-35 PRESSURE-ACTUATED SWITCH MANUALS. 16-page manual deals with operation, service, and overhaul instructions for pressure-actuated switches employing a Bourdon tube. Second manual gives descriptive discussion of the terms of pressure switches.—Meletron Corp., 950 North Highland Ave., Los Angeles, Calif.

R-36 STRENGTH TESTER. 4-page bulletin describes and pictures maker's "Model L" Universal Tester for testing materials from fabrics to metals, of tensile strength from a few pounds to 160,000 psi.; shows construction for tensile, compression, transverse and shear testing. Describes handling of flats and rounds; fixtures for fabrics, cord, rope, wire, wood, and adhesives.—W. C. Dillon and Co., Inc., 5410 W. Harrison St., Chicago 44, Ill.

R-37 "SHOP AGENTS PLAN." 8-page pocket-size booklet explains maker's plan for individuals to become shop agents; sell company's line of tools.—George Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y.

R-38 "WHEELCO COMMENTS." Vol. 8, No. 1 4-page issue of this house organ contains information on maker's strip chart recorder.—Wheelco Instruments Co., Harrison & Peoria Streets, Chicago 7, Ill.

R-39 ELECTRICAL INDICATING INSTRUMENTS. 26-page bulletin discusses company's engineering and production facilities; functional simplicity of construction; accuracy; electrical and physical specifications; hermetically sealed instruments. Describes and illustrates maker's standard instruments, with specifications, applications and information on how to order.—Marion Electrical Instrument Co., Stark St. Gate, Manchester, New Hampshire.

R-40 "THE GENERAL RADIO EXPERIMENTER." 8-page Vol. 23 ,No. 6 issue of this house organ contains articles on a compact radio-frequency capacitance measuring instrument, and inexpensive, basic instruments for the laboratory. —General Radio Co., 275 Massachusetts Ave., Cambridge, Mass.

R-41 RAIL DEFECTS. 4-page bulletin titled "G-Men of the Rails," contains information on methods of detecting rail defects; explains detector car from which a crew works.—Sperry Rail Service, Hoboken, N. J.

R-42 HYDRAULIC REMOTE CONTROL. 4-page Bulletin 2001 describes and illustrates hydraulic remote controls, giving special industrial applications, specifications, etc.—Sperry Products Inc., Danbury, Conn.

R-43 MANOMETERS. 4-page bulletin illustrates and describes maker's manometers, said to have seven new improvements. Illustrations and standard specifications are included.—King Engineering Corp., Ann Arbor, Mich.

R-44 ULTRASONIC THICKNESS GAGE. 4-page bulletin illustrates and describes maker's "Reflecto-gage," for determining thickness, lack of bond, bore eccentricity.—Sperry Products Inc., Danbury, Conn.

R-45 AUTOMATIC STEAM GENERATORS. 4-page folder describes and illustrates maker's "Cyclotherm" automatic steam generators with automatic firing sequence, electronic controls, etc. Gives performance data for both steam and hot water generators from 10 to 300 hp.—Cyclotherm Corp., Dept. 190R, 90 Broad St., New York 4, N. Y.

R-46 STANDING WAVE RATIO AND RF POWER MONITORS. 6-page bulletin describes and illustrates maker's models for measuring RF power and standing wave ratio on coaxial transmission lines over a wide range of frequencies and power levels; other models for open-wire transmission lines, etc.—M. C. Jones Electronics Co., Bristol, Conn.

R-47 SOLID ADSORPTION DEHUMIDIFIER. 16-page Bulletin 214 discusses adsorption dehumidification as related to material preservation and other uses. Emphasis on method of evaluating machine performance.—Pittsburgh Lectrodryer Corp., P. O. Box 1766, Pgh. 30, Pa.

R-48 INDUSTRIAL RECORDERS AND CONTROLLERS. 32-page illustrated catalog lists maker's complete line of recorders and controllers for measuring temperature, speed, gas analyses, electrolytic conductivity, pH, etc. Catalog gives specifications for single-point, two-point, and mul-

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